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Changing military, government and industry roles to meet new challenges

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* Abstracts reviewed and selected by international experts.

Roles and Working Practices in the Changing Environment, Evolving Technologies and Techniques

Dr M Goodfellow, Defence Evaluation & Research Agency, UK

ROLES AND WORKING PRACTICES IN THE CHANGING ENVIRONMENT, EVOLVING TECHNOLOGIES AND TECHNIQUES

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ABSTRACT

Technological change and the renewed focus on military capability (rather than equipment) as the key driver of acquisition are creating a more "joined-up" environment for T&E. The talk reflects on the implications of this. Examples of computer-based visualisation of trials results are used to illustrate how technology is contributing to improved practice in T&E and the delivery of enhanced value to customers.

INTRODUCTION

Although I am a relative newcomer to the T&E business, I was struck yesterday by the focus that this community puts on the requirements of the war-fighter. Recognising that T&E is a means to an end, and not an end in itself, puts the community in good position to adapt and respond to the rapidly changing environment, the theme of today's sessions.

The programme for this event has been deliberately structured so as to enable us to debate the issues in context and this leads me to acknowledge the hard work of the many organisers and presenters who have brought the event into being. I know very well the considerable effort it takes to prepare papers and support the organising committees and I pay tribute to all who have clearly done such a fine job.

My brief this morning is then to focus us on the changing environment and the challenges - or rather the opportunities - which this presents in terms of roles, practices and technologies. I aim to do this by looking at 2 of the dominant drivers for T&E: the focus on military capability and prospects of technological improvement. Let me briefly lift the lid on each of these.

MILITARY CAPABILITY

Firstly, I want to make some observations on the way in which a capability-centred view amplifies trends towards complexity and concurrency that were already present in defence acquisition. These are the result of, for example, a generally less intense but far more unpredictable set of threats, rapid succession of generations of electronic and software systems, COTS components and their associated obsolescence issues, extended platform life and of course digitisation of the battlespace, with its effect of joining almost everything to everything else. At the single equipment level, one may well be dealing with multiple concurrent upgrade cycles as well as dependencies on other equipments without which the first equipment cannot deliver worthwhile performance. Those other equipments might well be C4/ISTAR assets comprising a mix of legacy and new equipments, all subject to some form of incremental acquisition. The capability viewpoint extends this to different classes of equipment, possibly operating in different environments in classical terms but all contributing to the military capability concerned and probably to others too. The point of reminding you of all this is that it describes a highly complex and

concurrent environment in which decisions and judgements cannot sensibly be made in isolation. Research, Development, Technical Assistance, OA and T&E will have to be significantly "joined up" than hitherto, which could cause some discomfort to established attitudes. Does this give the traditional adjudicators significant ownership and responsibility over the result of the acquisition? Does it matter?

The shift towards an holistic vision of military capability gives us the opportunity to join-up our T&E forces with those of other acquisition players to support a single goal of military effectiveness. There is nothing new of course in 'jointery'; the US has for at least two decades been successful in combining DT&E and OT&E and the UK has done quite well in conducting 'purple' T&E on air systems. However, it is perhaps only when we all focus on a single high level goal that we truly realise the complexity of the undertaking. Already, with Smart Procurement, we have seen the adoption of the systems engineering (SE) approach as a pragmatic response to managing acquisition complexity. It does this by thoroughly tracking the interdependencies and taking proper account of the impact on military capability when making design or programme decisions. Of course, there is nothing fundamentally new about this as a concept, but the availability of effective computerised toolsets to support the process makes it a good deal more practical to apply the necessary rigour in practice. We should look to apply these principles to the management of T&E. In Figure 1, I have represented four planes on which T&E will always be at work: these are concept demonstration, development & qualification; equipment effectiveness and military capability.

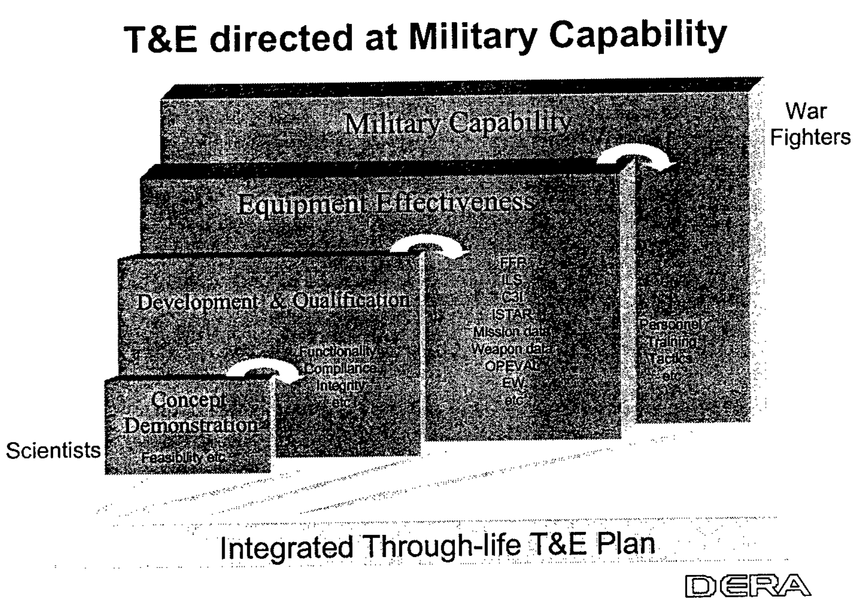

Fig 1

The natural tendency in prosecuting the T&E task is to think from the left-front-bottom corner and expand the T&E activity in-line with developing requirements. Systems Engineering informs us though that we need to be much more rigorous in capturing and engineering our requirements against the high level product – military capability. By examining these early, across all four planes we will start to generate a comprehensive set of requirements that can be addressed by means of a fully integrated T&E plan. As well as optimising the T&E solution this approach also has significant potential to influence system design. For example, it is almost certainly more cost effective to design for test at the outset rather than incur the cost, time and flexibility penalties associated with special-to-test instrumentation fits. If, at the same time, we address measurement requirements of training (and indeed engineering support) we start to see the potential of this approach. We cannot be involved in such potentially worthwhile judgements without a well-informed understanding of the requirements at all levels. This is the more "joined up" approach that I referred to earlier. However, it is not for the faint hearted, because it implicates the T&E engineer in the ultimate achievement of the desired military capability in ways that traditional methods of working did not.

The process for managing integrated T&E is highly amenable to the systematic approach inherent in systems engineering. By continuously reviewing and updating goals at all levels, scarce T&E resources can be directed at priority areas of technical, programme and cost risk. This stands in contrast with the procedurally based approach which has everyone fulfilling traditional roles in isolation without properly weighting the priorities or impacts. Integrated T&E brings other challenges too. Almost by definition, integration demands trust and respect between the players. That is:

- understanding and accepting each others roles, even when these are necessarily in tension;
- sharing all relevant information and data;
- protecting other parties' IPR;
- agreeing common goals against end user requirements

There are some difficult cultural issues and I will be interested to here other views on these during the plenary session.

TECHNOLOGICAL IMPROVEMENT

Having talked in broad terms about the focus on military capability, I plan to use a specific example to illustrate the way that technological improvement is being embraced within the UK T&E community. I will do this by considering the recent application to T&E of the technology of visualisation.

Visualisation is a pseudo-3D graphical representation by computer, of information derived from the real world. The technique can be applied in several ways to the testing of complex weapons systems and platforms and to mission rehearsal and training, providing a rapid and cost effective means of transferring knowledge.

What, then, are the benefits of using this technology in a T&E scenario? In the first instance, it can ease the task of trials planning and preparation. It allows problem solving before the event itself takes place, by viewing the intended location and assets from multiple perspectives. It can be used as a pre-trial training tool for participants, thus reducing the risk in the programme.

If the images on the screen are driven by the data from tracking instrumentation, visualisation can also allow real-time trial observation of the sequence of events. This is particularly useful for underwater or air-to-air engagements, which may otherwise be unobservable.

Now that the use of T&E assets is being extended to mission rehearsal, visualisation can play a significant part in familiarisation of aircrew, for example, with the practice mission before it is flown. This applies equally to the normal conduct of trials.

In cases where trial data sets are used to build and validate models, visualisation assists with step-through post trial analysis, enabling normally inaccessible properties to be viewed by fusion of trial data with visual images.

Training now forms much of the business of the UK T&E Sectors, and visualisation has been applied successfully to post sortie analysis, speeding the development of operational tactics by means of rapid after-action review.

Finally, visualisation can be driven by telemetry data to allow more precise control of the systems involved in a trial.

Let us take a look at some examples of these developments...

<u>Trials planning and risk reduction</u>

This visualisation of a bombing range in Norway produced for the RAF is being used to assist in trials planning and preparation. As it is possible to view the terrain from any position, one is immediately able to assess what problems may develop from the placement of sighting equipment (Electro-optic trackers, etc.) during a proposed trial in this extreme terrain. Furthermore, pilots can be introduced to the layout of the range and be shown the routes to be flown in a trial, gaining a good understanding of what to expect and do, before entering a foreign facility.

The total visualisation details approximately 400 sq. km of mountainous terrain using DTED level 1 data producing 9200 polygons over which a map showing roads, buildings, contour lines and other geographical points of interest is placed.

Note the F18 used in this visualisation is enlarged to five times its normal size to aid the presentation.

<u>Real-time engagement observation</u>

The visualisation of the British Underwater Test and Evaluation Centre is currently being completed. It was designed originally for a quick debrief on trial events, but is being adapted to enable tracking system data to be fed into the visualisation in real time, allowing remote observation of engagements in progress.

This visualisation is based on an accurate database, generated from underwater soundings of the seabed, and from DTED Level-1 data of the surrounding land. This detail allows strategic operational centres, such as the range control buildings, hydrophones, and other monitoring equipment to be added quickly to the database.

It is now possible to view the submarine, torpedo, target and all events as they happen, from any perspective, thus providing a major aid to understanding of the results.

<u>Mission rehearsal</u>

With growing pressure for our Armed Forces to perform operations with minimal collateral damage, mission rehearsal is becoming of major importance. By creating a detailed and accurate database of one of our airfields and the surrounding range area, its use for mission rehearsal can be assisted. With precise scaling and placement information, it is possible to view events in real time or quickly after they have been recorded. This can be used to prepare aircrew for a mission being simulated on the range, or for a quick after-action review.

The model can easily be edited using the appropriate software, and proposed trials or actual data quickly incorporated. The scaling is such that one unit in the model represents one metre, and the placements of the bombing pads, runways, and buildings, correspond to their positions on

Ordnance Survey maps. The images used in the model were extracted from digital photographs or from digital video.

Model building and validation

Here we have a visualisation of a test firing of a 155mm shell from an AS90 gun, over a Multiple Receiver Doppler Radar system (MRDR). MRDR can be used to determine the movement of the shell in all three planes and in roll, pitch and yaw, without the need for mathematical integration. This motion can accurately displayed within a visualisation, which assists in validating a six-degree-of-freedom model. As any imaginable viewing position can be obtained, properties can be viewed which are normally inaccessible due to engineering limitations or safety considerations. We can, in effect, fly with the shell, studying its motion from behind and alongside.

Post-trial or post-training analysis

This application of the visualisation process gives an example of how it can assist in the comprehension of complex high-speed interactions. Not only is the information on the flight of the aircraft, target and missile in this theoretical engagement brought to the viewer via a graphical representation, but also an informative 2D overlay is included to provide details of various important variables. For example the system can be used to analyse an air-to-air weapon firing, the progress of which can be reviewed on screen. Development and demonstration of amendments to the tactics can be greatly assisted.

One of the most profitable applications of this technique is post-sortie analysis during missile practice camps. It is even feasible that the scenario could be changed while the aircraft and the target were still airborne, as a result of the observations made in real time.

Real-time control of systems

In this final example, the data relayed be telemetry from an unmanned aircraft has been visualised to assist with its control. As you can imagine, controlling a platform of this type from a remote ground station is not easy. By providing the operators with a moving display as shown, they are much more easily aware of the attitude and status of the platform ant the enhanced targets which it tows.

There are several benefits, which include reduced training time for operators, reduced risk of abortive sorties during trials or missile practice camps, and improved safety.

I hope the example of visualisation has demonstrated the way in which T&E techniques are being adapted to reflect the changing nature of military operations. As many colleagues at home and abroad have observed, we need to address the need for operational T&E seriously if our assets are to continue to be of assistance. There is, in addition, ever more emphasis on the use of T&E facilities for training. The frequent use of models and simulations to aid decisions in the equipment acquisition process, demands a T&E capability which is of immediate application in developing and validating these models. We expect these trends to continue, and of course, we shall continue our efforts to adapt within the T&E community as history unfolds.

Test and Evaluation Activities in the Pacific Region

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TEST AND EVALUATION ACTIVITIES IN THE PACIFIC REGION

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Abstract.

The Pacific region is home to some of the largest air, land and sea ranges in the world. Their missions include ballistic missile and intercept testing, air and sea launched missile testing, drone engagement testing, conventional weapons and munitions testing, electronic warfare testing and joint battle-space environment testing. In the current Defence climate of fewer dollars, fewer people and fewer but far more demanding tasks, the survival of their capabilities is becoming increasingly at risk. The assertion is made that that they will be incapable of meeting the demands of the future in the absence of a cooperative investment plan that is prepared with strategic intent.

This paper explores the role that the International Test and Evaluation Association [ITEA] has played in the Pacific region to improve professional dialogue in T&E, enable relationships to be developed and hence catalyse the taking of new and highly successful initiatives.

I am hopeful that the newly formed UK Chapter will be encouraged by this - as there is much evidence to suggest that most of us are trapped in the 'here and now' with little spare capacity to commit the resources needed to secure the capabilities of tomorrow. This obsession with the present needs to change -- before some capabilities are lost to humankind forever.

Test and Evaluation Activities in the Pacific Region

Introduction

A claim that has never been challenged by anyone I know, is that the International Test and Evaluation Association (ITEA) is the pre-eminent professional society for staff with an interest in Test and Evaluation (T&E) - whether its aerospace (like the theme of this forum) or anything else. The need for such a professional society was first recognised in the United States in the early 1980's, where errors of judgement lead to the costly failure of many complex military systems that were being developed in the United States at the time. And as with all failures, humankind was given opportunity to learn from those mistakes - or be bound forever to repeat them.

ITEA Successes

With the establishment of ITEA, opportunity therefore presented itself to learn from such mistakes - and this was done with so much success that, in 1987, science fiction author Isaac Asimov prophesied that the new science of T&E would become our global early warning system - to prevent stargazers from tripping over their technological feet.

And in bringing that prophesy into reality, I believe that the United States learned from its military mistakes so successfully that in 1987, the fundamental precepts of T&E were institutionalised across all Federal Departments via an edict from the Office of Management and Budget.

Since that time, this focus on the fundamental T&E precepts has migrated to: the Australasian region through the establishment of the Southern Cross Chapter; the Middle East through the establishment of the Israeli Chapter and to Europe through the vision of David Kimberley and the establishment of the UK Chapter.

A Compelling Need for Global T&E Dialogue

I strongly believe that this globalisation of ITEA and the global appropriation of the fundamental T&E precepts is now a compelling and essential response to both the Revolution of Military Affairs and the Revolution of Business Affairs.

For none of us, in Government or Industry are immune from this. We are no longer dancing to national tunes but to the tune of rapid globalisation and the market pressures and competition that this brings.

As a compelling example of commercial competition, you only have to witness the radio-frequency spectrum auctions where spectrum critical to both national and coalition force operations is at grave risk of being lost forever.

To the present day, ITEA members have been the pioneers at the fore-front of change and ITEA itself has been the catalyst for drawing the T&E community together, improving the availability of post-graduate education, and facilitating professional dialogue via international conferences that are now held regularly in three of the major world regions; the Americas, Europe and the Asia/Pacific.

I am therefore hopeful that this presentation will be an encouragement to the UK Chapter - because in the early days of the Southern Cross Chapter formation it was like firing a flare from a life-boat to see if anyone else was out there.

Impact of Globalisation

So, other than encouraging the UK Chapter, what am I am doing as the ITEA Pacific region representative at a European T&E Forum. Well, lessons shared are lessons learned, so I'll be sharing some. As well, I'll be taking opportunity to tell you what we're famous for in the Pacific - so we can be considered to be part of the global solution to what must now be addressed as a global problem - investment planning for the future.

For with respect to the future of T&E, we are now talking about security of investment in national, regional

and global resources - which are under aggressive attack from commercial interests - notably airspace, land-space, sea-space and of particular note 'radio-frequency spectrum space'.

As an example of the latter, recent spectrum auctions have left the European ranges with only 20MHz of harmonised telemetry spectrum with which they are expected to test their weapons systems as well as their space and aerospace platforms of the future - both military and civil. 20MHz does not even enable an inter-range cooperative drone engagement to occur today - let alone consider what might be on the weapons system drawing boards of tomorrow. And believe me, this is only the beginning. So please support the newly formed International Consortium on Telemetry Spectrum [ICTS] to help defend these interests.[1] For the future of space and aerospace endeavours are now at significant risk - in both military and civil application. And it doesn't stop there.

All of the essential test and training infrastructure is under attack so I can only promise you that it won't go away - it will occur with increasing tempo and ferocity. In response, we may need to act locally - within our own national or regional borders or spheres of influence - but we must think globally - and we must be continuously vigilant

Range Uniqueness

In the past, from my Pacific experience, I've seen: Australian platforms and weapons systems being tested on European and US ranges; and US and European platforms and weapons being tested on the Australian ranges. Usually, this business is non-competitive. We go to particular ranges - not principally because of their investment in the technology of test - but because they offer some environmental or topographical advantage. And this is where a global investment strategy is most needed - as without it - the ranges will not be separately defendable on a domestic-use-only basis. And either we stand together on this or we will surely fall separately.

A Forecast for the Pacific

In the Pacific region, the member nations arguably have some of the most rapidly expanding and sometimes volatile economies in the world. But these national economies are becoming increasingly tenuous owing to the increasing reliance on high technology systems to improve and maintain the prosperity, security and quality of life of each nation's citizens. And common to all these high technological systems, both military and civil, are the devastating consequences if they fail - where loss of life, property, trust, money - or all of these - are inevitable - and where today's errors readily become tomorrow's headlines.

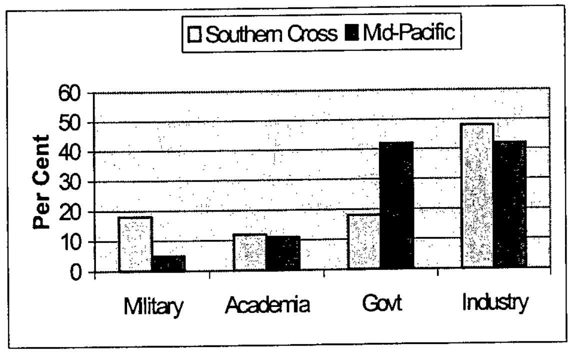
The presence of ITEA in the Asia/Pacific region therefore heralds a new opportunity for all Pacific nations, large or small, to understand how to develop and field high technology systems with known confidence and with predictable consequences - by replacing the proven failures of conventional wisdom with the lessons shared and learned among experienced T&E professionals.

[1] See http://www.telemetry.org for details and updates.

The Pacific Chapters

At present, two Chapters of ITEA are already established in the Asia/Pacific region, the Southern Cross Chapter (in Australia) and the Mid-Pacific Chapter (in Kauai). Their demographics are illustrated at Figure 1.

Figure 1 Pacific Chapter Demographics



The oldest of these Chapters, the Southern Cross Chapter, was formed in 1992 and its membership presently spans Australia and New Zealand.

As a service to the T&E community in the Pacific Region, the Southern Cross Chapter has already hosted eight annual conferences on T&E -- with the year 2000 event to be in Queensland later this year. And last year, the Mid-Pacific Chapter hosted an enormously successful Test and Training Workshop. I am confident it will be the first of many.

Pacific Region - Claims to Fame

So what are we famous for in the Pacific region apart from regularly holding T&E professional forums. Well I was going to suggest our friendliness - but I then recalled that the discoverer of Australia was an Englishman by the name of Captain James Cook and that he was killed in the Pacific in the 'Friendly Isles' - which is today located near another source of unfriendliness - the French Pacific nuclear test site.

That aside, some of us at least are famous for our friendliness - so come on down to our T&E Conference in Queensland later this year to judge for yourselves. Known as SETE-2000, the event will be co-sponsored by the Southern Cross Chapter of ITEA and the Systems Engineering Society of Australia [SESA].

Australian Successes

Other claims to fame?

Australian Department of Defence

Well as part of its success story in the Australasian region, the Southern Cross Chapter of ITEA has facilitated the development of Australian Defence Test and Evaluation Policy and acted as the catalyst for the production of a Directory to the Australian Defence-owned Test Ranges and Facilities - and its ultimate inclusion in the International directory.

More recently (and principally through its Defence Science members) it has also nurtured the establishment of an Australian Defence Simulation Office to guide strategic investment in Modeling and Simulation [M&S].

You will no doubt recognise that M&S is an important component of the T&E tool-kit - as it embraces the 'prediction tools'.

What remains to be done under the Australian T&E policy is to harmonise this with the investment planning for the 'observation tools' - the test and training ranges and facilities - which, apart from their traditional role in weapons systems testing are now essential to assess the fidelity of models and simulations.

Research and Education

The Southern Cross Chapter has also pioneered the establishment of a "regional" centre of excellence to facilitate post-graduate education, training, research and technology transfer in T&E. Known as the Australian Centre for Test and Evaluation (ACTE) and located at the University of South Australia, ACTE has already achieved considerable international respect. The Centre is now frequented by both civil and military researchers, students and staff from: the Asia/Pacific countries (such as India, Korea, and Singapore) from Israel and from Europe; and it has also surpassed expectations -- by attracting collaborative research investment from beyond the Asia/Pacific region - such as the United States and Europe.

Perhaps this is living testimony that T&E cannot be departmentalised, or regionalised - as it is truly global in nature. And more recently, ACTE has expanded to incorporate the education and research needs of the Systems Engineering community - to now become the Systems Engineering and Evaluation Centre [SEEC]. This initiative, for both the Systems Engineering and the Test and Evaluation communities enables further promotion and facilitation of constructive dialogue on their intersecting interests.

Need for good University Links.

Both ITEA and SEEC/ACTE are success stories. And the more I read about the pioneers in this exciting new field of science and engineering, the more I believe we should celebrate them - and take opportunity to join with them - to continuously expand and improve on the foundations they have already laid.

In the United States, I know there is good dialogue occurring on T&E with a number of Universities and their research centres. I'm reluctant to name them for the fear of leaving one out - but perhaps notable is the establishment of the Test and Evaluation Research Centre [TEREC] at the Georgia Technical Research Institute [GTRI] - as it was through GTRI that the Australian centre got up and running and we are indebted to the people of vision there who made this possible. And I bear personal testimony that this was a gracious and unselfish act in this day and age of 'every man for himself'.

Likewise, I know the Mid-Pacific Chapter has strong links with the US University system and has notably held a number of their Chapter events with the participation of the High Speed Computer Centre at the University of Hawaii.

In the United Kingdom, I understand that a nucleus for education and research was recently established with the Defence Engineering and Systems Group of University College London - so please support that for all you are worth. Because if you are like us 'Down Under' - the pressures of modern development programmes leave no time to think - meaning that the whole workforce is captive to the 'here and now' with little freedom or capacity to think about investment strategies to meet the demands of tomorrow.

The Pacific Region - Major Capabilities

Before exploring an investment strategy - let's look at some specific examples of what we are famous for in the Pacific - because perceptions can be deceiving. An example of what I mean by this is evident on a map produced in 1996 by National Geographic which states some quantitative measures for the investment that the United States Department of Defence has made in its military reservations and test and training ranges.

The map witnesses that the military reservations in the US occupy: "*27 million acres found mainly in the South and West, which are home to 220 threatened or endangered species and contain 100,000 archaeological sites.*"[2]

Well we might all wonder how the European or the Pacific Region investments compare to that - but I don't think any of us in Europe or the Pacific will be trying to out-do those figures as an exercise in one-up-man-ship.

So just what is the Pacific Region famous for? Well to help answer that question I asked both the Southern Cross Chapter and the Mid-Pacific Chapter to provide some example inputs - and the coverage is partly shown at Figure 2. Kwajalein gets highlighted because its the hardest to find on a map.

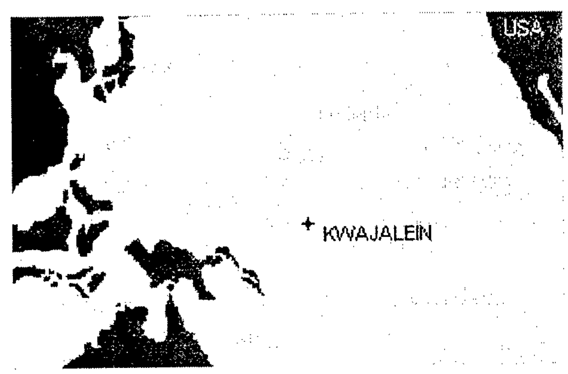


Figure 2 A Section of the Pacific Region

Marshall Islands - Kwajalein Missile Range

The Marshall Islands. Population 43,380. Home to the Kwajalein Missile Range. What's it famous for? Mission support for theatre ballistic missile and intercept testing; and space debris monitoring among others,

Hawaiian Islands - Pacific Missile Range Facility

The Hawaiian Islands. Population 1.18M. Home to the Pacific Missile Range Facility [PMRF] - one of the largest test and training ranges in the world. What's it famous for? Multi-national integrated test and training. Its

[2] National Geographic map, *Federal Lands and the Fifty States*, published Oct 96

area of coverage is illustrated at Figure 3 and its connectivity with other ranges is illustrated at Figure 4.

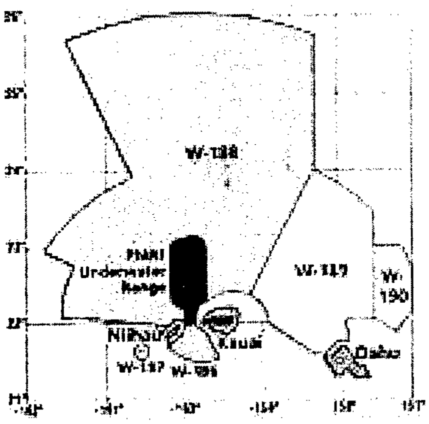


Figure 3 - PMRF Area of Coverage

With reference to Figure 3, PMRF has the ability to provide simultaneous real-time tracking information on participants, targets, and weapons on its 42,000 square miles of sea and airspace

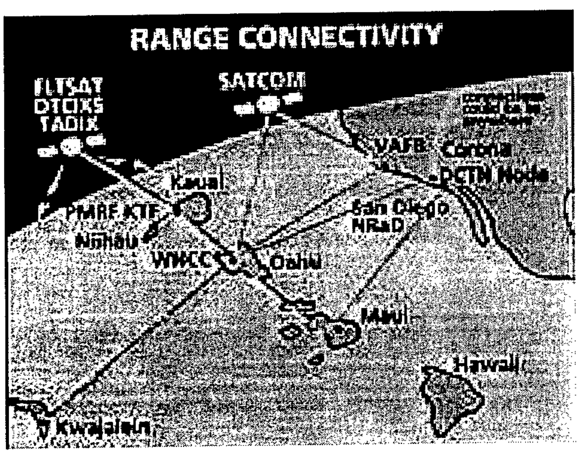


Figure 4. Range Connectivity

Australia - multiple ranges.
Australia. Population 18.3M. Home to multiple air, land and sea ranges - which do not currently have central ownership. In this scenario, the Australian Director of Trials[3], in conjunction with the single service T&E principals is currently planning to better coordinate T&E direction and resource investment. We wish them well.

Proof and Experimental Range. The Army's Proof and Experimental Establishment is located at Port Wakefield in South Australia - it is coastal and tidal - and famous for the soft recovery of projectiles.

[3] In Australia, the Trials Directorate is a component of the Defence Science and Technology Organisation and under the current leadership of Colonel Brian Hall.

Jervis Bay Range Facility. This range is located in New South Wales and provides mission support for drone engagements and through-life telemetered missile firings for our Air Force and Navy.

The Woomera Range. This range is illustrated at Figure 5. The South Australian component of this occupies 127,000 sq/km and enjoys virtually unencumbered airspace.

Its famous for its unrestricted views of the horizon, its golf course - voted the second worst in the world - and even more famous of late because there is not enough domestic work to keep it alive.

Its official mission? It's searching for one!

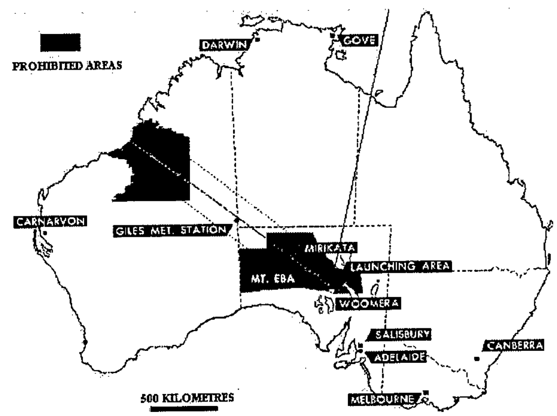


Figure 5. The Woomera Range

New Zealand. Population. 3.5M. Home to Industrial Research Limited - where the privatisation of many traditionally Government research activities has already occurred.

Industrial Research Limited [IRL]. What's it famous for? In my opinion, and as an encouragement to us all - its resourcefulness and its apparent lack of organisational barriers to doing things productively.

The example given me, which was a maritime example, testifies to this; viz; I imagine that anyone who has a professional interest in T&E has read the US DoD Simulation, Test and Evaluation Process [STEP].

Well it seems that the New Zealanders don't call it STEP - they call it "*the common sense process*".

The process they followed to predict and measure the dynamic loads on a surface vessel in a variety of sea states almost precisely follows STEP and yields outcomes that are crucial to understanding a vessel's seakeeping, structural integrity and human comfort factors.

Their *'common sense process'* included the development of a finite element model, a prototype, an installed test, and a simulation that was followed up by sea trials to assess the fidelity of the predictions.

The trials research vessel, illustrated at Figure 6 was 'borrowed' from the NZ water police.

Resourcefulness? Well the same people who did this work for the NZ maritime community, did the same for: a flutter programme on an A4 Skyhawk for their Air Force and for the sea-worthiness and structural integrity of New Zealand's contender in the Americas Cup.

Figure 6. IRL-NZ Trials Research Vessel

I also understand that the IRL folks spin-off their experience to other diverse fields ranging from human hip prosthesis to the manufacture of plastic bags! I can't speak for the United States or Europe, but in Australia, I suspect we'd be tripping over all sorts of federal, state and industry 'research fiefdoms' if we tried to do the same.

And on that note, I don't plan to speak for the European or the US or the Israeli experience of T&E but in Australia, *national* leadership on T&E is currently conspicuous by its absence. And everyone it seems is expecting Defence to take leadership on the issue.

Range Alliances - A Compelling Need.

At the grass-roots level, there is current talk of forming a Pacific Range Alliance that would give connectivity and load-sharing between the major Pacific Ranges such as KMR in the Marshall Islands, PMRF in Kuaui and the Woomera range in South Australia.

I dare to suggest that it not only needs to be talked about - it needs to happen quickly - and it needs to be part of something even bigger which will enable 'plug'n'play' of all range participants globally. For without that global vision, I believe a number of things will happen.

- Interoperability testing will suffer exquisitely. [If not addressed it means that the next generation weapons systems and platforms destined for coalition force or peace-keeping operations will not 'plug'n'play' and become legacy systems before they are ever fielded.]
- Unique range capabilities will be lost forever as it will be unaffordable to recover them. [topography, environment - arctic, desert, tropical, electromagnetic environment etc]
- Every range participant will be faced with unique spectrum allocation and electromagnetic environment incompatibility problems at every range on Earth.
- We will continue to be 'penny wise and pound foolish' - as currently there is a thousand-fold more attention being paid to how to cut salary and maintenance costs at the ranges compared to the level of attention being paid to optimising their ability to avoid T&E progamme costs.

T&E Economics - Some Illustrations

Let me illustrate that last point with a couple of examples. In the 1990's, our Air Force invested in a Transportable Telemetry System at a cost of a few million dollars. On it's first deployment to Woomera it detected problems early in a weapons programme - which, if they had remained undetected would have cost the Department of Defence twice that to rectify. It paid for itself on its first application with a dividend to Defence of 100%.

So what's happened since then? No-one has kept any records of the cost savings or cost avoidances that have been enjoyed on any subsequent programmes. So, inevitably, its now being down-sized and possibly out-sourced to minimise staff salaries and maintenance costs - in an absence of informed understanding of how this will compromise its future 'cost-saving or cost-avoidance' capacity.

This same philosophy applies to any investment in T&E capabilities. For some confirmation on this I referred to a DSTO study that was performed on the International Follow-On Structural Test Programme [IFOSTP] for the F/A-18 fighter aircraft. The cost of investment in the test programme was $50M. The "cost avoidance' that this investment yielded was $3.5B. Similarly, looking at the sums for a single weapons clearance programme: the investment cost was $2.6M and the return on that investment (through cost-avoidance) was $16.5M.

Try adding up those investment returns for every weapon that ever needed to be cleared from a military weapons platform!

The point to be made is that cutting the costs of maintaining the T&E capabilities may well compromise their potential return on investment quite dramatically.

Why aren't we looking at the economics of T&E from an investment strategy perspective so that we can make informed decisions. We cannot afford to be 'penny wise and pound foolish'.

Measuring Range Productivity

Based on the economic rationale explored, I would strongly assert that the principle measure of productivity for a Test Range or Facility stands on one of the fundamental precepts of T&E - to detect problems while they're cheap to fix.

Some dispel this precept as technical risk management or risk mitigation - but it's far more than that. Its an economic imperative that we really do understand the dividends of T&E - the return on investment.

Everywhere I see, the cost of maintaining the test ranges and facilities is coming under intense scrutiny - but too often I see no reference at all to the economic return being enjoyed because of their existence. This is a great tragedy and one that compels and deserves all of our attention - while it's not still too late.

Need for a Global Investment Strategy

Well, having explored what some of us may be doing wrong, let's see what happens when we do things right. What would be the expected outcome of a 'global' investment strategy.

- global range connectivity standards
- all range participants 'plug'n'play.
- seamless interoperability testing

- ranges build on their strengths and not their weaknesses
- distributed subject matter experts
- cost-sharing on R&D investments in next generation range technologies
- able to meet surge demands
- an environment that will inspire bright young science and engineering graduates
- investment economics 'understood'
- cross-cultural enrichment

Who needs to consider these things? Well, as a piece of personal advice, we might need their help later - but we should not start with our politicans.

As an example, I can't speak for the behaviour of the US Congress, or the British Parliament or the European Union - but recently, in Australia, a number of High School girls witnessed a sitting of the Australian Parliament and were interviewed on a national television transmission immediately afterwards.

Asked what they thought of the experience, one girl replied, '*Well if we behaved like that we'd all be expelled*!'

The destiny of T&E must therefore lie in our hands, the people who own it, practise it and have responsibility and accountability for it. And, a global T&E investment concept that promises large scale cost avoidance, interoperability, connectivity and compatibility on a world scale must be addressed urgently and with strategic intent.

We need to reveal, by design, the chasm between where we are and where we need to be - to fuel the desire to close the gap.

We need to understand the economics of 'give me a million dollars to spend on T&E and I will save you two.' And like the outstanding companies in industry, we must plan to get to the future first - to create the environment in which the future can flourish - safely and economically. To do this, we need to be brave and not timid, we need to be transformationary not evolutionary , and we need to consider leap-ahead concepts not creep-ahead concepts.

And as a final flourish, which will perhaps put my personal credibility on the line. Give me a million dollars to spend on T&E and I will promise to save you two - but I will expect 5% of the dividend, the cost avoidance that I achieve for you. This will not only encourage me to do even better next time, I will use it to invest in my own readiness to serve your future needs.

A Recommendation

I'd like to make a call to everyone in the T&E 'business' to consider these things. In the current RMA/RMB climate we need to enable our decision-makers in Government to introduce new technologies into civil or military service with known confidence and predictable consequences --- and to leverage the international competitiveness of our industries by helping them to place 'test-proven' products on the global supermarket shelf.

So if you would like to monitor or contribute to what's happening in T&E in your region please contact your local Chapter President. If you'd like to start your own Chapter, talk to your Regional Vice-President or ITEA HQ.

For if we continue to be "survival centred, maintenance budget based and competition driven", I believe unique capabilities will be lost forever to all of humankind. Instead, I believe we must be "vision lead, capability centred and cooperation driven" - and be passionate about getting to the future first.

History may well teach us that "vision without dollars is hallucination" - but we must all have the product before we can sell it - so we do need enough dollars and enough commitment to manufacture the vision - and we need to start now.

I fully recognise that today, we live in a multi-cultural society but as some evidence of divine precedence, try Proverbs 29:18; 'Without vision the people perish."

We need people who are able to get their arms around these broad concepts; people of vision who think with strategic intent and in systems-independent terms and at systems-independent levels of abstraction; people who know what the science and technology horizons are; and people with a fire in their belly to make it happen. And in responding to the winds of change, we need the leadership of the future and not the studied helplessness of the past,

As an international professional society, ITEA has neither the authority nor the funding to address this - but I strongly believe that its members and its forums are the right place for it to be explored and discussed. So will everyone please treat yourselves to establishing this vision - for I believe you're worth it.

Acknowledgments.

My thanks go to all who offered their insight during the preparation of this paper. Mr Cliff White, for his news on the establishment of the Australian Defence Modelling and Simulation Office, Mr Graeme Finch at IRL, Mr Stu Burley at PMRF, Mr Jack McCreary at KMR, Col Brian Hall Australia's new Director of Trials, Professors Peter Sydenham and Stephen Cook at SEEC/ACTE , Dr Patricia Sanders at BMDO and Mr John Gehrig at DOTE for their continuing inspiration and support, Dr Jim Cofer at GTRI and, importantly, Dr Graham Richardson at DERA for his vision, hospitality and invitation to assemble and present these views. Lastly, my thanks go to all at ITEA and to the ITEA membership - without whom the tyranny of distance would perpetuate the isolation of the T&E community.

Drivers of Global Security and Their Implications

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Drivers of Global Security and their Implications

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Abstract

Project *"Insight" was* conducted three years ago by the Defence Evaluation and Research Agency (DERA) to establish the key drivers likely to influence global security in the period 2015 to 2040. The project was initiated under the auspices of the UK Technology Foresight Defence and Aerospace Panel, aiming to provide guidance for strategic planning in defence.

To help tackle the increased uncertainty and complexity of the future, the project undertook a series of interviews across a wide population of informed people around the world. A small number of focused studies were also conducted. A substantial period of synthesis engaged recognised defence and scenario planning experts, including an international symposium. The project produced three related outputs:

- A set of core drivers characterised in terms of the issues they raise, the outcomes they imply and associated indicators.

- A range of contrasting macro scenarios illustrating the way in which differing outcomes for the set of drivers might produce qualitatively different international structures and relationships.

- A proposal for an evidence-based hybrid planning strategy – 'the Insight method' – encompassing both long range planning and nearer term crisis management.

This paper outlines the Insight method before presenting a summary of the 'drivers' aspect of the work and their implications. The UK Cabinet Office's Strategic Challenges project, run by its Performance and Innovation Unit, recently drew on an enormous range of futures work, including Project Insight. Its consolidated paper confirms the currency of the Insight work.

1 – Insight method

The study method adopted by Insight is also the basis for the so-called Insight method, as illustrated in Figure 1. Briefly, the primary objective of the Insight method is to establish a framework within which events can be more effectively mitigated or exploited. This involves responding to events and indicators related to previously characterised outcomes, optimising process and organisation so that events can be responded to organically, and maintaining a portfolio of investments that provide as broad a coverage of possible outcomes as is affordable.

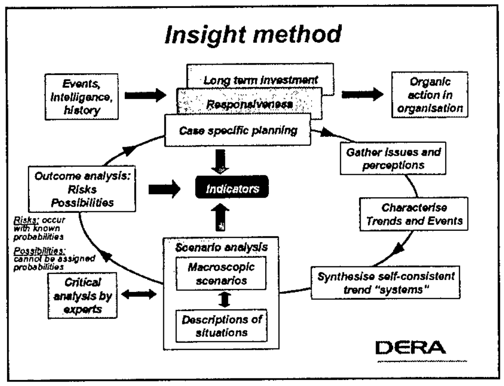

Figure 1 – The 'Insight' method

2 – 'Insight' drivers of global security

The trends and events were characterised to capture knowledge about their rate of change, plausible divergencies, and stability in the context of wider systems, and for convenience were grouped under the eight driver headings in Figure 2.

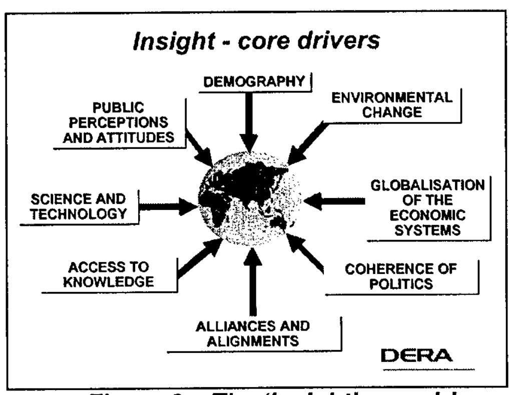

Figure 2 – The 'Insight' core drivers

I – Demography

Scope of driver: This driver area includes all aspects of change in population size and composition. In many areas, indicators such

as age and size of population will be well documented in government censuses. In unstable regions population size and composition may have been changed significantly by war, famine or disease, and accurate figures will be difficult to establish. Some governments may also publish misleading figures. Less quantifiable indicators should also be used to assess projected demographic change; for example, increasing literacy rates, particularly among women, can be expected to lead to declining birth rates.

Potential key security issues

- Rapid population growth is leading to growing competition for resources, mass migration and regional instability, as well as pressures on immigration policies of the richer nations.

- The aspiration of the poorer 90% to live like the richer 10% is creating new demand on natural resources, and undermining traditional communities.

- Growing populations of unemployed and disaffected youth in developing countries threaten civil stability (the potential effect of so-called 'testosterone power').

- Growth in poorer countries, in terms of sheer numbers and economic clout, challenges economic and political dominance of the richer nations.

- Ageing population in richer countries, and their growing needs, will increasingly drain public resources; it also means fewer young people, available for, or willing to join, armed services.

- Increasing gap between the number of engaged, educated and wealthy individuals and the poor and disengaged. Many nations will have more people than they need for successful economic growth. Those disengaged and without purpose could be an increasing source of tension.

II – Environmental change

Scope of driver: This driver area includes all aspects of environmental degradation or improvement, both anthropogenic and arising from natural geological, climatic or other causes. Trends might include air pollution levels arising from industrial and domestic use of fuel, sea pollution levels and their influence on fish stocks and human health, carbon dioxide levels in the upper atmosphere, forest clearance and biodiversity. Some indicators will be quantifiable – measurement of water tables or of airborne and waterborne pollution over time, for example. Projected environmental change should also be assessed using indicators such as public attitudes to car use or awareness of industrial pollution, and the degree of international political co-operation over matters such as anthropogenic climate change.

Potential key security issues

- To counter effectively the growing threat of global climate change we require trans-national consensus and robust global institutions that do not yet exist. It is a problem that cannot be solved unilaterally. How do we persuade nations to develop sustainably, and persuade developed nations to reduce consumption?

- Access to resources such as energy and minerals continues to be a source of tension. This may increase as more countries industrialise and populations and expectations increase.

- Climate change and migration patterns could shift patterns of disease distribution.

- Growing populations are placing increasing pressure on key resources such as water and productive agricultural land, which can be the spur of both ethnic and inter-state violence, with international ramifications.

- Forms of pollution such as nuclear emissions are not constrained by state borders and can exacerbate tensions between polluting nations and their neighbours, inciting retaliation.

- Large numbers of 'environmental refugees' are possible (300-500 million by around 2000), resulting in regional destabilisation.

- The aspiration of the developing world for higher standards of living places unprecedented pressure on the global environment and resources, which have until now been monopolised by the West. How can this problem be managed?

- Will the constraints of pollution enforce a 'wartime economy' of close regulation and rationing of damaging agents and processes?

- How do we influence nations whose emissions may degrade the local or global environment?

- Many in the population increasingly call out for action on environmental issues. If governments do not act effectively then how may people seek to solve this problem?

- Use of environmental damage as a tool in conflict, for example, the Iraqi burning of oil wells and the release of oil in the Gulf, and the draining of Marshlands in S Iraq, use of defoliants by the US in Vietnam. Aggressive actors may exploit environmental vulnerabilities or use them to coerce opponents.

III – Globalisation of economic systems

Scope of driver: This driver area encompasses aspects of all economic change, but particularly focuses on the growing interdependence of economic systems within regions and around the world. The direction of capital flows and international investment as an indicator of current and potential economic growth should be measured, as should government legislation such as the reduction or increase of tariff barriers and limits to international trade and foreign direct investment. Interdependence is increasingly enhanced by the creation of economic areas such as the European Union and the Association of South East Asian Nations, and the development of these should be monitored. Economic globalisation may lead to the marginalisation of less economically dynamic individuals as well as states or whole regions from the global economic network. Evidence of this marginalisation, leading to resentment and instability within and between states, should be sought. Other indicators of anticipated economic change might include government policies to redistribute wealth, education levels, unemployment, and environmental pollution – which have the potential severely to disrupt regional and national economic systems.

Potential key security issues

- Governments are steadily losing control over their economies to international institutions or the organic 'hand of Adam Smith', with all that implies for reductions in their power and influence.

- Shifts in the location of economic power may generate shifts in the location of diplomatic and military power, with unpredictable political ramifications as 'old' nations readjust.

- A growing proportion of mid-ability people in the developed nations will not offer a globally competitive level of 'worth' commensurate with acceptable income. Disenchanted under-classes may become an endemic cause of internal conflict and breeding ground for trans-national aggression.

- The strength of national economies affects defence spending, e.g. the West experiencing a decline, mirrored by a rise in the East.

- With growing global competition, and smaller internal markets, ability to maintain a national defence industry is becoming harder.

- The globalisation of the arms industry leads to a proliferation of both weapons and weapon-making technologies among nations that are or might one day become adversaries.

- Growing economic interaction and the rise of 'interdependence' between nations may improve relations or foster mercantilistic competitions.

- Current economic trends are, in some areas, leading to a growing gap between 'haves' and 'have nots' and a decline in social cohesion and stability both within nations and between nations.

IV – Coherence of politics

Scope of driver: This driver area spans the range of factors that impinge upon the strength and legitimacy of political power, the form and impact of formal political process and the circumstances that determine its nature *within states*. The strength and stability of political regimes should be measured through the analysis of the support bases of political leaders within the domestic polity and in the population of the country. The international status of the regime also needs to be considered in this driver area, as international condemnation of a regime may have a significant impact on its stability at home.

Important domestic indicators of political strength will be the level of popular involvement in the political process, the state's human rights record, the level of violence surrounding electoral processes and civilian control of the armed forces. The emergence of alternatives to the leadership within or outside the government, perhaps of ethnic groups, should be considered.

Although the jurisdiction of a regime may be recognised internationally, this may not be reflected in the actual level of political control that a government is able to exert over its territory; the existence of the rule of law throughout the territory is an important indicator of a government's effectiveness.

Potential key security issues

- The type and nature of national leaders, their intent and degree of public support.
- Declining confidence of populations in governments and inhomogenities in support threaten legitimacy and the government's power to act in the face of perceived threats, internal or external.
- Hesitancy gripping the latest wave of democratisation in the developing countries and the former Soviet Union raises spectre of tumult and unpredictable politics.
- Generalised access to knowledge and technology outside the sphere of state influences have empowered a range of hitherto 'hidden' actors.
- The increasing number of actors in the international arena, combined with the growing number of issues that motivate them and the means at their disposal to pursue their objectives, has greatly increased the complexity of global politics.
- The shift from state-centric sources of power to a range of non-state actors has resulted in much less predictability and greater turbulence.
- Traditional criminal groups – including terrorists, and drug and arms traffickers – have greatly increased their effectiveness and legitimacy through the extension of their international networks.
- The growing number of failed states means that the traditional interlocutors of international agencies and governments in the developing world are losing their legitimacy and capabilities, in some cases resulting in power voids.

V – Alliances and alignments

Scope of driver: The character and strength of international alliances and alignments – both formal and informal – is assessed in this driver area. The continuing existence, role and status of the North Atlantic Alliance and the nature of the transatlantic relationship will be important indicators of change to the British and European security environment. The emergence of security alliances from regional economic and political groupings such as the Association of South East Asian Nations and the Organisation for African Unity will be important to monitor. Military coalitions, including peace support operations, are included in this driver area. The legitimacy of such coalitions is increasingly established through United Nations Security Council Resolution; therefore the status and effectiveness of the UN are important determinants of the coherence of these alliances. The state of the UN is also one of the more concrete indicators of the existence of an 'international community' in any meaningful sense. The development of the Organisation for Security and Co-operation in Europe will be important to assess.

Informal alignments between states and the emergence of dominant regional powers will also be included in this driver area; for example, analysts may monitor tensions between the governments of the European Union, or look for indicators of Chinese ambition to extend its influence over political affairs in South East Asia. Indicators of change in this driver area will be the establishment of international treaties and agreements, the strength and effectiveness of regional organisations, patterns of trade (particularly the arms trade) and, importantly, personal relationships between heads of government.

Potential key security issues

- The character and strength of international alignments (broadly defined) and formal, inter-state security alliances, contribute directly to the security of the international political system. In the absence of unequivocal, external threats, which have a unifying effect, formal security alliances may become more difficult to define and sustain. Instead, international security may become a function of *ad hoc* arrangements and 'virtual security alliances'.
- Identification of a potential adversary has obvious implications for the general military posture to be adopted, on the procurement of military equipment, and on other areas such as military training, reserves and force generation. Formal security alliances are called into question because of the diminution of military threat and because, without a 'clear and present danger', domestic defence budgets are reducing. In these circumstances, it is difficult to see how formal security alliances could be replaced by self-contained national forces, other than by very large powers. So it must be asked both why and how states will commit themselves to formal security alliances.
- Security alliances formed to meet a crisis or during a conflict will require some form of legitimacy. This may be established by the

UN. Where the establishment of legitimacy is neither automatic nor universally accepted, the result may be that *ad hoc* groupings (i.e. less formal, less durable security alliances) are formed.

- What role does a state wish to play in the post-Cold War security environment? Is the motivation to be simply national defence and security, or the creation and maintenance of a global security framework? An isolationist or unilateralist trend among the richer and militarily more capable states will be increasingly incompatible with the co-operative approach to both national and international security that emerging global problems will require.

- Effective security alliances should not be assumed to be a western/northern phenomenon; as developing states become more powerful and become more organised regionally and by sector, they may be able more effectively to seek their individual and collective goals, and protect their interests.

VI – Access to knowledge

Scope of driver: This driver area covers all aspects of the explosion in access to information that have transcended geography and transformed many aspects of political, social and economic life in the twentieth century. All forms of communication and education should be examined, from Internet use to literacy rates and availability of basic schooling.

Control of information is increasingly difficult for governments to achieve, and it will be important to monitor how individuals and small groups are using the widespread availability of cheap communications to further their political ends. The power of the media can be enormous, so ownership of the media is of crucial importance. The effects of broadcasting on public attitudes to all kinds of issues – from government policies to marriage to fashions in clothes and food – may be difficult to predict and should be monitored carefully. Changing levels of television and radio use, newspaper readership, literacy rates and the availability of public and private transport are useful indicators of change in this driver area.

However, the effects of increased access to knowledge will often be less quantifiable, as individuals' reactions – even to the same media message – vary enormously. Perhaps more important, therefore, may be analyses of the effects of changing patterns of information availability by regional experts, who should have more detailed understanding of the society in question and language fluency.

Potential key security issues

- Access to knowledge is changing the balance of power between individuals, non-state actors and the state, leading to more pluralist-based decision-making processes with a concomitant decline in the ability to react quickly and decisively in emergency situations.

- The media are having a growing impact on both government actions and public perceptions of the way their governments work, with a growing ability to influence policy.

- Cultural globalisation as driven by the media is creating expectations in poor countries of a kind and quality of lifestyle that may not be attainable. This may cause uncontrollable tensions within under-developed countries.

- The global media and information technology have put a powerful new tool in the hands of terrorists and other pressure groups, one that can both ensure anonymity or publicise their activities to a global audience.

- Governments will lose the ability to control availability of information and set chosen internal agenda.

- More information will be disseminated via 'info-suck' rather than edited media. This will have a wide range of implications, especially increasing the power of the capable.

- Validation of information will be a serious issue. Organisations will be able to endorse veracity, or that have a reputation for accuracy, will gain in influence.

- Global movements of information and E-money will subvert legal controls, creating uncontrolled markets for information services.

- As the reliance on information technologies for economic power grows, the premium on protecting information systems is also increasing, though this may not be possible to do comprehensively.

- Access to knowledge will facilitate the proliferation of skill required to produce weapons, especially weapons of mass destruction.

- Effective husbanding and exploitation of knowledge will become the primary discriminator in business success, requiring a big adjustment to balance sheet-based

accounting principles. This 'whole new ball game' of info-assets could have destabilising influences.

VII – Science and technology

Scope of driver: This driver area covers all technological innovations, the implications of their development, and their influence on the security environment. Although technology in warfare is an obvious example of how this driver influences the security environment, military technology is only one aspect of this broad area.

Developments in medical science may have an important impact on population size and public attitudes. Communications technologies are likely to continue to grow, with diverse consequences. Genetic engineering may provide benefits through increased crop yields or the elimination of hereditary birth defects; but they may wreak unexpected havoc. It will be important to monitor not only scientific breakthroughs but also their (often surprising) impacts on society.

Potential key security issues

- Technological innovation continues apace, with developments which can disturb the balance between aggression and mitigation, trigger social change, and pose fundamental challenges to legal frameworks.

- Barriers to exploiting technology are reducing, and the traditional monopoly of the richer countries on research and development is eroding.

- The shift in balance between civil and military research makes proliferation of technologies imparting military superiority much harder to control; technological edge in a specific chosen area of capability may be available at modest cost, even to non-state actors.

- We are witnessing enormously rapid progress in understanding of genetics and of the nature of the human mind; this may unlock a Pandora's box of technological innovation that could impact strongly on society and the conduct of warfare.

- Much current development gives emphasis to the ability to design and adapt products in a very short time with extensive computer simulation prior to prototype construction; this has potential to transform the product lifecycle, especially in the military sector.

- Scientific ignorance and an emphasis on the 'curative' powers of technology have spawned an optimistic culture that neglects efforts to anticipate problems; this approach may founder during the Insight time window.

VIII – Public perceptions and attitudes

Scope of driver: This is perhaps the broadest and most nebulous, but also the most important, of the drivers. It covers change in popular beliefs about a whole range of issues, from attitudes to government taxation to perceptions of foreigners or ethnic minorities to religious beliefs.

Opinion polls are the most obvious, although not perhaps the most effective, indicators of public attitudes – the answers given depend on the questions asked, and may reveal what the respondents merely think they *ought* to say. Other indicators of changing public attitudes might be varying levels of participation in religious activities, *ad hoc* political protests and social movements, and changing family structures. Like the 'Access to knowledge' driver, often the most effective indicators of changing trends in public perceptions and attitudes will be provided by regional experts, who should have more detailed understanding and language fluency of the society in question.

Potential key security issues

- The growth of trans-national groupings, reinforced by globalisation of knowledge, may create new axes for the development of perceptions and attitudes, driven by fundamentalisms, professional groupings, sectional interests and the media.

- Trends toward public 'insularisation' in the face of less visible threats make it difficult for governments to target public resources to counter them. Armed forces need to think carefully how to educate peoples to understand their role and relevance.

- The heightened sensitivity to casualties in the richer nations makes public support for military action difficult, and this may impose serious constraints on doctrine and tactics.

- The growth of religious fundamentalism has been a feature of the recent past. Will this trend continue and couple more strongly into the wider security scene, or will other effects such as globalisation and increasing wealth drive in the opposite direction?

- The freedom to act on a wide range of issues is constrained by public reaction, which has caused major shifts in the actions of governments, multi-national companies and other institutions.

- Managing public attitude, e.g. through information warfare, may become a critical defence / security capability.

- The attitude of short-termism and defeatism prevalent in the richer countries regarding many global security problems deflects attention from underlying causes and possible preventive actions.

3 – Implications for defence capabilities

Offerings from armed forces

The analysis of trends and scenarios suggested the need to look more openly at the 'offerings' that defence provides to its stakeholders. These are presented under two headings; Defence missions (Figure 3) and Diplomatic missions (Figure 4).

Offerings from armed forces

Defence mission types:

- **defend attack against homeland**
- **support dependent territory or treaty obligation**
- **succeed in regional interventions**
- **coercion to mitigate aggressive threats**
- **protect (or exploit) physical, economic or information infrastructure**
- **support to civil power**

DERA

Figure 3 – Defence mission types

Offerings from armed forces

Diplomatic mission types:

- **promote state's influence and signal commitment**
- **intelligence and information**
- **protecting trade and economic interests**
- **deterrence and denial of opportunity**
- **peace keeping / enforcing**
- **arms control**
- **humanitarian relief**
- **support for governance**

Figure 4 – Diplomatic mission types

Instruments of security

Through brainstorming the kinds of capabilities and instruments of security that might be required, it is possible to produce a list of war-fighting and architectural capabilities, as shown in Figures 5 and 6 respectively.

Instruments of security

Warfighting capabilities:

- **ability to threaten and coerce**
- **battlespace superiority**
- **mobility and sustainability**
- **joint readiness**
- **destruction of assets and infrastructure**
- **tactical RISTA and operational planning**
- **holding ground**
- **close-in and special forces**
- **counter WMD**
- **information warfare, psyops**
- **constabulary force**

Figure 5 – Warfighting capabilities

Instruments of security

Architectural capabilities:

- **presence and international standing**
- **ability to marshal military, economic and diplomatic levers to achieve a result**
- **deterrence through commitment to timely and proportionate action**
- **intelligence**
- **intelligence on potential actors**
- **planning and rehearsing missions**
- **re-establishing governance and infrastructure**
- **sanction enforcement**

Figure 6 – Architectural capabilities

Capability portfolio analysis

On this basis it is possible to do a high-level capability assessment, such as the one illustrated in Figure 7. In this example, warfighting capabilities are analysed against each of the four macro scenarios (outlined in Appendix A) and the issues addressed, asking how we think current plans stack up, whether they are appropriate, should investment be increased or decreased, *et cetera*. Although the example given is purely illustrative it is possible, say, that in three of the four macro scenarios 'destruction of physical infrastructure' may not be as relevant as at present and that current plans may be quite well aligned to that type of situation.

Illustrative capability portfolios

WARFIGHTING CAPABILITIES	WEB OF NATIONS	SUBSIDIARITY	FRAGMENTED	BLOCS
Ability to threaten and coerce	●	●	↑	●
Battlespace superiority	↑	↑	●	●
Mobility and sustainability	↑	↑	↑	●
Joint readiness with allies and ad-hoc partners	↑	↑	?	●
Destruction of physical infrastructure	↓	↓	↓	●
Protection of own infrastructure	↓	↓	↑	●
Tactical RISTA & planning	↑	↑	↑	●
Manoeuvre warfare	●	●	↓	↑
Close-in & special forces	●	●	↑	●
Counter WMD	↑	●	↑	●
Information warfare	●	●	↑	●
Constabulary forces	●	●	↑	●

● Current plans appropriate ↑ Changes in scale/form implied ↓ Some dis-investment possible

Figure 7 – Portfolio analysis – warfighting

As far as architectural capabilities are concerned, the main point to be taken from the illustrative diagram on the left is that an abundance of upward arrows implies the need for a shift in balance of investment. Warfighting capabilities are still important, but we need to catch up with the architectural capabilities.

Illustrative capability portfolios

ARCHITECTURAL CAPABILITIES	WEB OF NATIONS	SUBSIDIARITY	FRAGMENTED	BLOCS
Presence and international standing	↑	●	↑	●
Ability to marshal military, economic, and diplomatic levers to achieve result	↑	↑	↑	●
Proportionate deterrence with balanced risk / reward	↑	●	↑	●
Intelligence on state and non-state actors	↑	↑	↑	●
Wargaming, planning and rehearsing missions	↑	↑	↑	●
Re-establishing governance and infrastructure	●	●	↑	↓
Sanctions enforcement	●	●	↓	↑

● Current plans appropriate ↑ Changes in scale/form implied ↓ Some dis-investment possible

Figure 8 – Portfolio analysis– architecture

4 – Summary of security implications

This section summarises some implications of the preceding analysis for the key issues of responsiveness, warfare and acquisition.

Responsiveness as a military capability

The inherent complexity and uncertainty of the post-Cold War security environment place a premium on the responsiveness of the armed forces as a military capability. It is vital that we foster agility in our processes, including the ability to adapt rapidly and apply existing doctrine and tactics, training and readiness, precision logistics and sustainability, and mission planning and control, as well as reducing the times involved in procurement, design and manufacture. Above all, 'plasticity' – the ability to adapt design and efficiently produce equipment to effectively meet changing requirements – and plasticity in one's systems offer a decisive advantage - in being able to delay procurement and keep open a wider range of options for longer.

Implications for responsiveness

At the same time we must seek to improve current approaches to crisis-management – for example, by developing processes that can reliably synthesise plausible future scenarios and provide a means for recognising and monitoring the indicators and signals associated with them. The process should be methodologically sound, unconstrained to the extent that it is free to step outside and challenge traditional thinking, and utilise both open and closed sources of intelligence information. Such a process is currently being developed by the DERA Project 'Insight' team in collaboration with the Policy Planning Staff of the Foreign and Commonwealth Office.

Implications for warfare

A range of implications for warfare stems from the greater number and diversity of actors seeking to shape and shove the course of global security, both now and in the future. It is clear that reliable intelligence and surveillance will become extremely valuable assets, and that intelligence information in the future will require knowledge not only on technological issues but also increasingly on the understanding of human behaviours and intentions. Increasing popular access to high-impact technologies such as the internet and global media has made it possible for ordinary individuals and groups to direct forms of persuasion, coercion and propaganda at other individuals and groups using means previously only at the disposal of states. Dealing with these new forms of potential threat implies a complex blend of military, diplomatic and economic actions by the state, with public opinion acting as the principal moderator of its behaviour. An adverse risk-reward ratio could result from the adoption of certain actions or policies by states, for example the targeting of charismatic leaders or gurus.

Increasingly, the integrated architecture of warfare will determine the overall operational effectiveness of a nation's forces, rather than the functioning of stand-alone weapons and capabilities. In an environment where total

knowledge and co-ordination – in short, omniscience – is tantamount to being a decisive weapon, information warfare, jamming and perception manipulation will likely become the routine modes of conflict. There may also be a considerable blurring between what we mean by the 'teeth' and what we mean by the 'tail', as the integrity of 'soft' background logistics and analytical support functions becomes crucial to ensuring the effectiveness of more traditional 'hard' kill components. In sum, future mission success is likely to be driven as much by the strength of the integrated, architectural 'glue' as by the effectiveness of war-fighting capabilities in isolation.

The 'Web of nations' and 'Fragmented' scenarios reveal the importance of maintaining joint training and readiness in anticipation of the need to form rapidly *ad hoc* partnerships and alliances. Role sharing remains a possibility in the 'Subsidiarity' and 'Blocs' scenarios, but is not a credible prospect in the 'Web' and 'Fragmented' worlds.

Implications for acquisition

Perhaps the central issue in terms of acquisition remains how the process of defence industry consolidation will play out and what implications follow from this for the state of the European and UK defence industries. It is possible that the industry is fast approaching a 'flip' point, as the disengagement of governments from their client suppliers leaves national research expertise to find its own way on the world market, and the ongoing consolidation of the industry world-wide creates a small number of truly global suppliers. The virtual versus vertical manufacturer structure, significant advances in flexible design / manufacture and the commodity trading of defence equipments all represent a significant shift away from traditional practices and could well become a reality within the next decade.

Industry must also come to terms with the increasing commoditisation of defence products and services, as governments shift from traditional processes of procurement to favouring off-the-shelf limited developments and technology insertion. At the same time the real military benefits of rapid procurement (that the short-term and low risk procurement process preserves options and allows programme 'headroom') may be offset by situations in which our adversaries are extremely adept at integrating and adapting the best technologies from the new global market.

Insurance vs. managing security

To summarise, should future defence planning attempt to provide insurance against every conceivable risk – which is going to be unaffordable – or should we move to a more sophisticated security planning strategy that seeks to manage risk in a more conscious way?

Although some of the serious risks that have traditionally driven defence planning and procurement strategies still exist in the post-Cold War world, they are now of a relatively low probability and (in many cases) come with long warning-times. Innovations in rapid procurement may be used to mitigate some of these risks.

The demise of Cold War bipolarity and the current period of systemic transition have, generally speaking, presented a host of more minor risks with a much higher probability of occurrence. It is time to focus more attentively on these, noting that our involvement in the potential crises associated with them is likely to be discretionary. Some form of metric is required to decide under what conditions we become involved. We will need to tailor capabilities accordingly, and deploy them with agility, sensitivity and precision.

The crucial issues remain. What is the degree of overlap? And, how much should we invest in attempting to mitigate each of these risk areas? Possible implications for the United Kingdom could be that we invest in a 'golf bag' of capabilities, with some 'clubs' held in quantity (where it is cost-effective to do so) and others kept latent using advanced technology and research. Capabilities could be chosen on the basis of where the United Kingdom adds most value to security, and discretionary activity could be modulated by what capabilities we have in the 'golf bag'.

APPENDIX A
OUTLINE OF MACRO SCENARIOS

The 'Insight' macro scenarios were constructed using a number of different approaches that examined the interaction between 'Political coherence' (engaged or disengaged) and 'Alliances and alignments' (formal or informal) drivers. The third driver dimension was 'Globalisation of economic systems' (interdependent or fragmented). Holding the other five drivers constant as a baseline assumption, the security aspects of these four macro scenarios can be summarised as follows:

- In the **'Web of nations'** scenario there are no major regional blocks with limited defence alliances, implying that NATO gradually weakens. Global security matters are increasingly orchestrated by the United Nations and enforced by *ad hoc* groups with aligned interests. The effective marginalisation of the developing world and underclasses within the developed world lead to growing trouble from sub-national and transnational groups. Nation-to-nation conflict is unlikely.

- In the **'Subsidiarity'** scenario, the realities of world politics encourage a leaching of power upward to regional groups for international matters and downward to provinces for more local matters. Nations group into effective unions and global security matters are increasingly dominated by a tripolar configuration of nation states centred on the American continent, Europe and Asia. The global security oversight is similar to the 'Web of nations' world, but increased regional coherence deters outliers more effectively and direct nation to nation conflict remains feasible though unlikely.

- In the **'Fragmented'** scenario, the process of globalisation and the rising power of international institutions seriously diminish the power of the nation state. While many nations retain their internal power and regional groups may exist, the security picture is dominated by a plethora of non-state actors pursuing diverse objectives. The probability of inter-nation conflict is higher here, especially in troubled parts of the world, and there is a much greater reliance on military intervention but with a poor risk/reward balance.

- The **'Blocs'** scenario envisages a total rejection and retrenchment from globalisation, with powerful economic and cultural groups forming but limited interaction between them. Governments are likely to be authoritarian, enjoying strong populist support from their electorates who favour extreme measures for dealing with terrorism and organised crime, even at the expense of individual liberties. The global economy undergoes a period of stagnation and the overall security picture is characterised by a stand-off balance of power between factions that ameliorates the likelihood of crisis to some extent.

Scope of Operational Test and Evaluation (OT&E)

J Manclark, HQ US Air Force Test & Evaluation, USA

United States Air Force
Directorate of Test and Evaluation

Scope of Operational Test and Evaluation (OT&E)

Mr Jack Manclark, Director

Fourth Test and Evaluation International Aerospace Forum

27 June 2000

United States Air Force
Directorate of Test and Evaluation

Purpose

- Objectives
  - Changing scope of operational test and evaluation (OT&E)
- Overview
  - Background
  - What has changed?
  - Operation Impact Assessment (OIA) - The new "E"
  - Coalition OT&E

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Background

- The law
  - United States Code (USC) - Title 10
- DoD implementation of the law
  - DoD Directive 5000.1
  - DoD Instruction 5000.2-R

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The Law - US Code, Title 10

"The term '*operational test and evaluation*' means --

i) the *field test, under realistic combat conditions*, of any item of (or key component of) weapons, equipment, or munitions for the purpose of determining the effectiveness and suitability of the weapons, equipment, or munitions for use in combat by typical military users; and

ii) the *evaluation of the results of such test*."

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Implementation of the Law - DoD 5000.2-R

"Operational test and evaluation (OT&E) programs shall be structured to determine . . .

1) the *operational effectiveness and suitability* of a system *under realistic conditions* (e.g., combat) and

2) if the minimum acceptable operational performance requirements as specified in the *ORD* have been satisfied."

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DoD 5000.2-R Mandatory Test Conditions

- "*Threat* or threat representative forces, targets, and threat countermeasures, *validated in coordination with DIA*, shall be used."
- "*Typical users* shall operate and maintain the system or item under conditions simulating *combat stress* and peacetime conditions."
- "The independent operational test activities shall use production or *production representative articles* for the dedicated phase of OT&E that supports the full-rate production decision, or for ACAT IA or other acquisition programs, the deployment decision."

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DoD 5000.2-R Operational Assessment Requirements

- "*Whenever possible*, an operational assessment shall draw upon *test results with the actual system*, or subsystem, or key components thereof, or with operationally meaningful surrogates."
- "*When actual testing is not possible* to support an operational assessment, such assessments *may rely upon computer modeling, simulations* (preferably with real operators in the loop), or an *analysis of information* contained in key program documents."

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Title 10
Initial OT&E (IOT&E) Restrictions

"... initial operational test and evaluation shall not *comprise an operational assessment based* exclusively on computer modeling; simulation*; or, an analysis of system requirements, engineering proposals, design specifications, or any* other information contained in program documents."

Operational Assessments (OA) versus OT&E

- Operational Assessments -
  How we think the system will work based on
  - Contractor or Development Testing
  - Programmatic Voids/T&E Schedule Executability
  - Operational Requirements
  - Modeling and Simulation
- Operational Test and Evaluation -
  How system actually works based on field tests
  - Operationally Representative System
  - Real Operators and Maintainers
  - Realistic Scenarios

M&S used to . . . Augment / Extend / Enhance

What Has Changed?

- *Introduction of Operational Impact Assessments*
  - Insights to CONOPS limitations, supporting systems shortfalls and joint system interoperability
  - Provided to using commands and warfighting CINCS
  - Feedback to Requirements Process
- *Streamlined acquisition*
  - Reduced government testing
  - "Insight vice Oversight"
- *Simulation Based Acquisition*
  - Use modeling and simulation early and throughout a system's life
  - System and threat models available for OT use

Air Force OT&E 1997

"The focus should be on mission-level evaluations*, assessing the impact of the system under test in its operational environment and taking into consideration all the variables that can contribute to mission success or failures."

** Title 10 OT&E plus Operational Impact Assessment*

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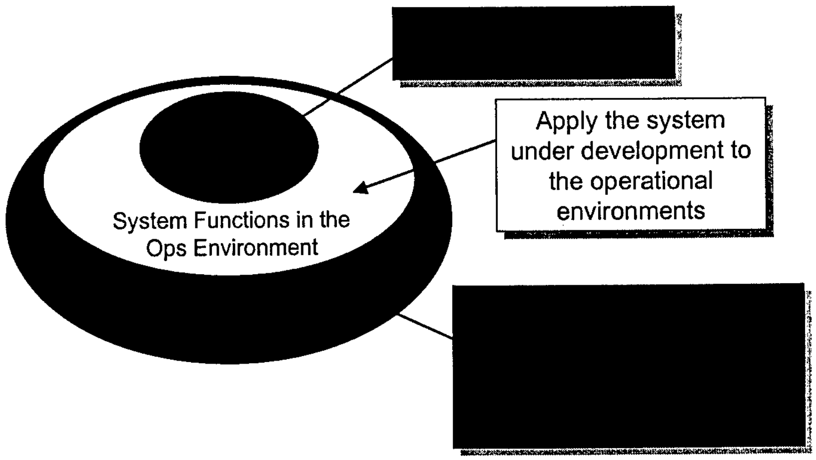
Developing the Evaluation Structure



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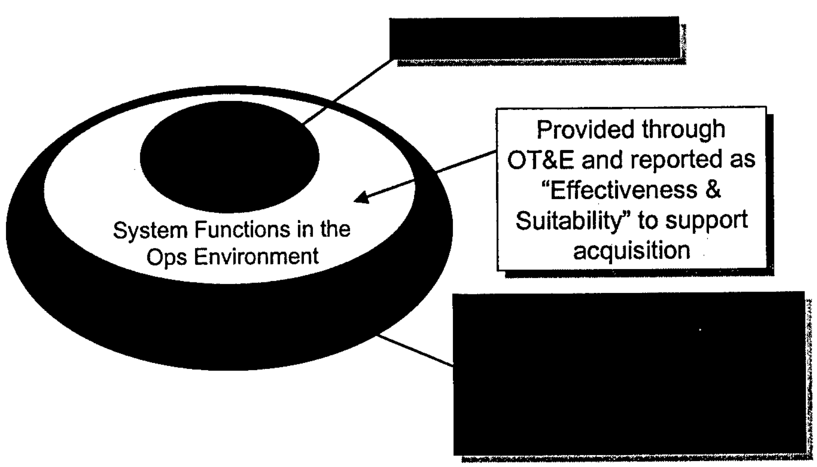
Conducting the Operational Evaluation



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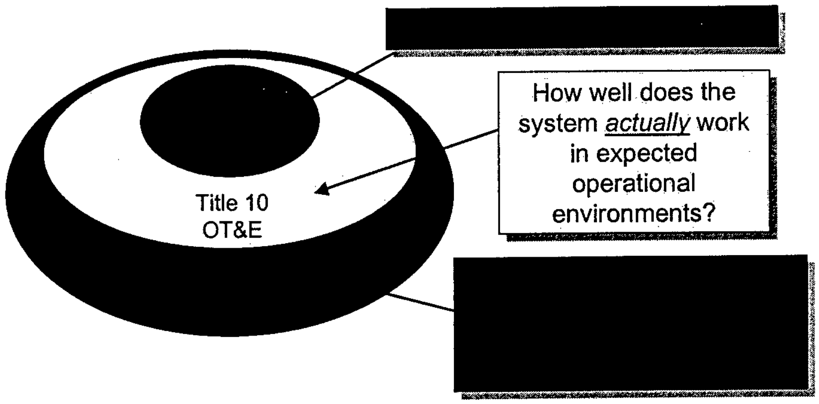
Tests, Evaluations, and Operational Impacts



Operational Impact Assessment

- Identifies potential impacts on battlefield operations
  - Deployment, employment and sustainment considerations
  - CONOPS/TTP Issues
  - Interoperability with other systems in the battlespace
    - Required support; e.g. communications
    - Potential conflicts; e.g. interference
- The question is: "Can the bridge be destroyed with the given resources (weapons, interfaces, information, etc.)?"
  - The question is not: "What is the value of destroying the bridge?"

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System OT&E vs OIA

- System OT&E
  - The effectiveness and suitability of the materiel system being acquired *when used by the typical military user (including its maintainer) under realistic combat conditions*; i.e., hands-on effectiveness and suitability
- Operational Impact Assessment
  - An assessment of the inter-relationship between the system under test and the operational environment within which the system is employed, to identify capabilities, limitations and force employment considerations.

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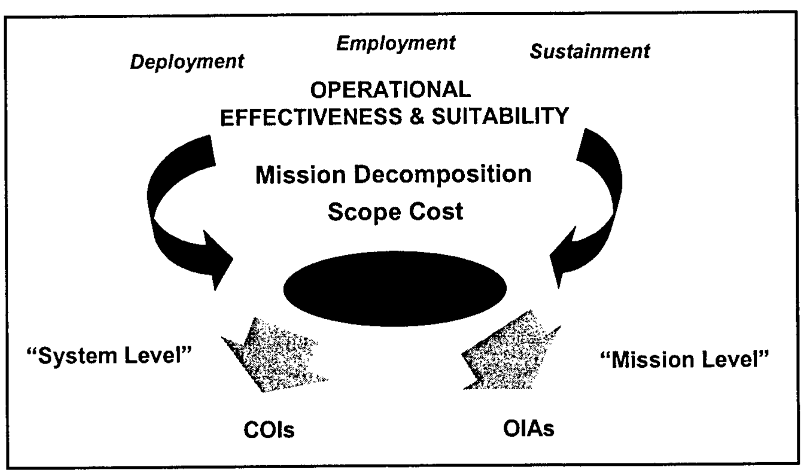
Planning and Reporting



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Observations

- Operational Impact Assessment *does* mean that we will identify potential impacts due to introduction of the system
- Operational Impact Assessment *does* mean that we can provide employment considerations and comment on mission area shortfalls
- Operational Impact Assessment *does not* require a mission level model
- Operational Impact Assessment *does not* mean that we have to quantify the system's military utility

Defining Coalition OT&E

- Traditional OT&E
  - Does the system meet expectations when operated by typical personnel in the intended environment
- Operational Impact Assessment
  - Are supporting systems, operational concepts and TTPs (tactics, techniques and procedures) adequate?
- Coalition OT&E
  - Can the system perform in conjunction with systems from other Services/Nations?

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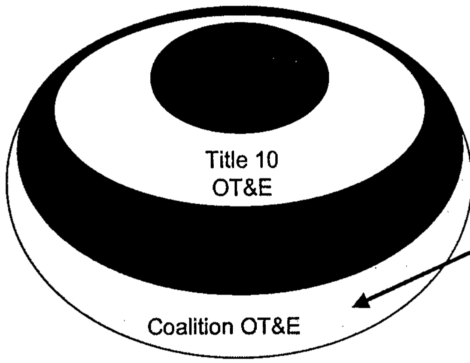
.... and Coalition OT&E



Multi-National Environment
Doctrine
TTPs
Interoperability
Electronic Compatibility

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Challenges

- Force Modernization and Interoperability
  - Force structure, doctrine and equipment differences
  - Rapidly changing technology
  - Transfer of Technology
  - Lack of standardization for interoperability and compatibility

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Challenges (con't)

- Differing Acquisition and OT&E Approaches
  - Highly structure US acquisition process designed to mitigate risk
  - More flexible European process to adjust requirements to meet cost constraints
- Funding/Affordability
  - Constrained military budgets - US and Europe
  - High competition among needs for modernization and readiness

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Forcing Functions

- Draft DoDI 5000.2
  - "DoD must have a framework for assessing the interrelationships among and interactions between various US and Allied systems To that end, milestone decision authorities shall adopt a "portfolio" or "system-of-systems" management approach to ensure that their reviews of individual systems include a thorough understanding of all systems related to the one under review."
- DOT&E Initiatives
  - Interoperability
  - Electromagnetic Environmental Effects

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Actions

- Develop Coalition OT&E Concept for a Selected Mission Area
  - Address NATO participants and capabilities
  - Establish requirements to inter-operate … operational focus
- Work toward more OT&E in Joint Exercises
  - Multi-Service
  - Multi-Nation
  - In conjunction with Joint Forces Command
- Propose Joint Test and Evaluation program as initial step

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Conclusions

- OT&E is becoming more important -- and more complex
  - Streamlined Acquisition
  - Simulation Based Acquisition
- The core mission has not changed
  - Evaluate the real system in the real environment with real operators and maintainers
- But, we have expanded that mission to provide assessments that are even more operationally relevant to the warfighting CINCs.
- Need to continue to improve OT&E to ensure relevance to the acquisition process and to the warfighters by implementing actions to meet the Commander's intent.

Coalition warfare demands we test and train together!

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DEPARTMENT OF THE AIR FORCE

MCMXLVII

UNITED STATES OF AMERICA

A Credible Guide to Future Warfare

Lt Col C Collett, Ministry of Defence, UK

A Credible Guide to Future Warfare

Lt Col Chris Collett
Directorate Force Development
Ministry of Defence, UK

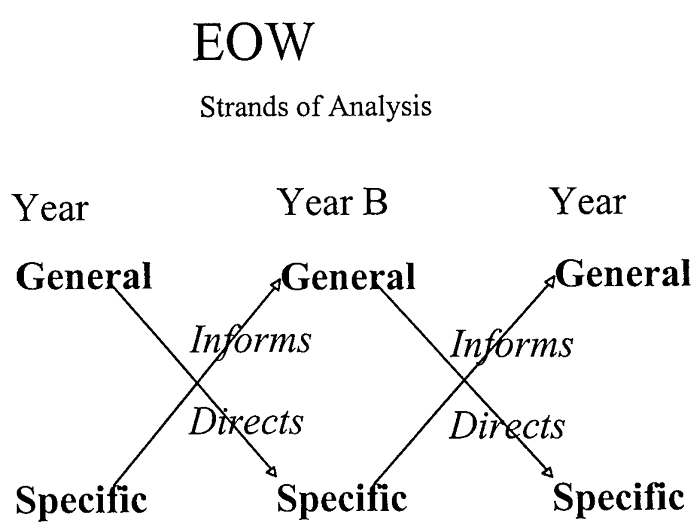
This presentation will cover three areas. I will begin by describing how the MOD is going about establishing the "credible guide" that the title claims in order to aid its medium and long term planning. I will then make a most un-MOD like leap by describing firstly some of the characteristics of future warfare and then secondly highlight some of the key factors in those conflicts. These last two sections are my personal views based on work carried out over the last two years and do not represent any official MOD position.

EVOLUTION OF WARFARE (EOW) PROJECT

The EOW project originated some three years ago when 28 academic papers were produced looking at sources of instability out to 2015. Those papers formed much of the intellectual basis for the subsequent Strategic Defence Review and were the starting point for the current project. EOW's aim is as follows:

"To provide a credible view of future warfare and other military operations in order to better inform MOD long term decision making."

EOW attempts to look out thirty years and therefore, has to consider an immense range of possibilities but it is not just an interesting exercise it is intended to influence real life decisions. EOW must, therefore, simultaneously look widely whilst applying a rigorous "so what" analysis to the concepts that emerge and thereby provide a robust audit trail for decisions. Hence the cyclical structure shown below wherein one year's general strands of analysis produces direction for the next year's specific studies the outcome of which is fed into the following year's general studies.



The general strands of analysis include.

Academic papers commissioned from experts outside the MOD.

Internal papers produced by MOD or other government departments

Scenario decomposition/analysis wherein teams of military, scientific and other experts dissect specially developed scenarios in order to highlight what tasks would need to be carried out and what broad order capabilities would be needed to accomplish them.

Wider technology work which exploits the future technology studies being carried out by DERA.

Outreach by which is meant that we seek to capture the views of as many others in the field as possible.

The specific strands of analysis can include:

Technology studies carried out in partnership with the DERA's Technical Top Team

Other Specially Commissioned Studies.

Conflict simulation games that allow us to explore in more depth novel technologies, strategies or tactics.

Collaborative Projects.

SOME CHARACTERISTICS OF FUTURE CONFLICTS

Here I step beyond reporting what the MOD is doing to give you some of my own personal (i.e. unendorsed) views about the future based on the work we have carried out over the last two years.

Firstly, what sort of conflicts are we likely to see? I would suggest that we are unlikely to be involved in traditional force on force conflicts along the lines of a strategic attack on NATO or close ally because of the conventional superiority we (by which I mean the Atlantic Alliance) now enjoy courtesy largely of the US. This is likely to endure but with perhaps narrowing margins due to a shrinking force structure less able to deal with multiple concurrent demands. Were this superiority to be lost, things might be different and the opportunistic competitor who takes advantage of either a temporary technical edge or our distraction remains a possibility.

What are far more likely are interventions of choice where national survival is not at stake and even the national interests are open to debate. My colleague Dr Hamid, has gone into detail on why we are likely to see plenty of potential for strife in the future and beyond this brief reminder I do not propose elaborate and certainly not to disagree with his conclusions. I would venture to say that this broad analysis is shared by at least the major western countries.

Sources of Strife

Population Pressure, Urbanisation, Poverty
Resources
Alienation along political, economic, ethnic, religious and "virtual" lines
Empowerment of non state actors

It might be argued that we will exercise our choice and not get involved with what are likely to be confusing, intractable and dangerous situations. I suggest however, that there are a number of reasons why on many occasions it will not be possible to ignore conflicts or other crises.

Firstly, the humanitarian impetus is likely to remain and indeed grow as global communications continue to expand. However, how fragile this impetus will be or indeed, whether a general "fatigue" will set in is debatable.

Globalisation will continue and probably increase the impact of local instability on the world economy and UK citizens' wellbeing. Today, 10 million UK passport holders reside abroad and 40 million travel overseas each year and this seems likely to grow.

Environmental damage is not confined to borders and as industrialisation spreads the potential for accidental or deliberate damage arising from conflict.

Global communications, travel and general migration means that conflicts can be expected to spill over into other nations even more so than we have seen to date. The mass movement of refugees is of course, better avoided than prevented or dealt with once underway.

It is important to also recognise why we may not be able to intervene. Domestic support is naturally crucial but an increasing degree of international agreement is also likely to be needed particularly as so many forces are likely to have multinational commitments. Interventions of choice imply a cost/benefit analysis must be carried out and it is likely that in the future this will be available far more reliably, far more in advance of an operation and to far more people. How soon before the evening news' computer graphics depict not only the military options open to allied forces but their cost in terms of lives and cash perhaps with the latter able to be represented in units of the viewers choice, so many hospitals for example? Finally, there will be many demands and limited resources. Choosing to commit to one operation will have to be done with an appreciation of its impact on the ability to commit to the next one.

Having painted a picture of a world with plenty demand for military action most of which will involve a finely balanced choice I will now suggest some of the options open to those who would oppose such interventions.

Initially an opponent will probably try to prevent an intervention ever beginning by perhaps, raising the perception of the likely cost and by attacking the base of support domestic and international. If that does not seem likely to work, he would be better to deny the intervening force physical access to the theatre either through political pressure on host nations, covert disruption of lines of communications or overt military action or the threat of it. Once faced with a deployed force an opponent is likely to attack the consensus that keeps it there perhaps by concentrating

strikes on one relatively weak member of a coalition. Finally, he may aim for sheer physical survival with the potential to conduct further offensive operations and hope to outlast the intervention force. The audience will be well able to think of weapons and tactics that could be used to prosecute such a layered strategy many of them falling under the rather catch-all term of asymmetric warfare.

Having now painted in another piece of the picture (whether it is credible or not is for the audience to decide) I would now like to suggest some of the factors that will be key in future operations.

INFORMATION OPERATIONS

Achieving and maintaining information superiority or indeed dominance will be of critical importance. It is the key enabler needed to achieve rapid success in complex environments (physical and political) with less risk and fewer unwanted consequences. To achieve this capability will require the fusion of multiple sources of information including both multispectral real-time sensors and diverse databases, to give commanders and planners a level of knowledge such that they are confident of *predicting* the actions of parties in an operation (friendly, enemy and neutral).

Operators at all levels also need to be able to accurately predict the outcome of *their own* actions. This capability needs to encompass everything from the physical results of a single weapon's arrival to its impact on the opinions of all significant populations. Achieving such a capability is therefore, far more than simply developing ever more capable sensors and suggests that more resources will need to be devoted to "soft" data collection, storage, expert retrieval and comprehensive adaptive modelling systems. The alternative to "operating" smarter is to operate (including to fight) with a heavier hand than may be financially or politically acceptable.

A major concern, however, is that the level of operational expertise called for above may be equally available to any opponent able to exploit commercial technology. It will be increasingly important to track the availability of real time information and expert systems in order to assess the threat to our operations and to develop countermeasures. The importance of information and communications in the civil world, technical progress and the degree of redundancy becoming available *may* make denial, disruption or physical deception impossible in which case more subtle techniques may be required. Clearly, as opponents inevitably acquire longer range and more destructive weapons it becomes more important to control their ability to *use* them if we are to retain freedom of action with acceptable risk. The alternatives would be to either increase the physical protection of more of our forces or place ever greater effort in pre-emptive destruction of threat systems. These two strategies are likely to be expensive and/or politically unacceptable.

MINIMAL DEPLOYED FORCES

Minimising the physical presence of deployed forces reduces the transportation and sustenance bills while obviously reducing the number of personnel at most risk. It is therefore, a vital goal to which increased use of stand-off or uninhabited systems, robots and higher levels of equipment reliability will all

contribute. However, the other side of the coin is that the remaining forces that still need to go in harm's way (and the size of this area is likely to expand) will be more fragile thus increasing the need for information dominance and other means of force protection. Those forces that must operate within reach of enemy systems (particularly in Peace Support Operations where physical presence is still expected to be critical) will also have to have assured access to support from afar that can match their timeliness demands. There are technological developments that could provide this but they are not likely to remove the requirement for on board sensors, weapons and defences completely.

STRATEGIC/TACTICAL MOBILITY

Both strategic and tactical transportation systems need to be much faster to both improve the chances of achieving surprise and to minimise the time their elements spend in areas of high risk. This desire for speed includes loading, unloading and turn around times. Developing systems that are less tied to traditional infrastructure such as ports, airstrips or railheads will be particularly important. Such facilities can be considered to be increasingly vulnerable in the future and being tied to them increases the difficulty of achieving surprise.

Ideally forces (and their logistic support) should be delivered from strategic distances almost directly to their objectives, which places an increased onus on protecting whatever transport systems used and blurs the distinction between strategic and tactical assets. Indeed if deployed forces could have organic theatre range mobility it would offer major operational advantages.

TAILORED PRECISION STRIKE CAPABILITY

The trend towards enhanced precision being required from weapon systems is not going to diminish. Striking must also be timely and restricted to the target and effect required. Inducing shock will be as equally desirable as achieving physical disablement as it adds to force protection and increases the speed of conflict termination. Conversely, the ability to "safe" weapons after release will be important and the ability to record the decision making process that led to their use (even down to individual rifle shots) will be critical when inevitably called upon to justify actions.

The advantages of using non lethal weapons against equipment are clear particularly when it was necessary to neutralise an area to be passed through or to disrupt opponent's C3 system. The ability to use less than lethal force against personnel to achieve temporary freedom of action will also be needed but is much harder to achieve in an acceptable manner. The advantages of using non lethal weapons are highly dependent on the previously discussed ability to accurately and confidently predict their results.

FORCE PROTECTION

Information dominance is the most critical element of force protection as long as it is coupled with the ability to either remove a threat capability before it is employed or to avoid its effects. Negating or living with the effects of future attacks will be increasingly difficult as lethality rises and acceptance of losses declines.

Chemical and biological hazards will continue to be major concerns. It is likely that the UK itself will be threatened by painful even if not militarily significant attacks (e.g. cyber or terror attacks) as opponents seek to prevent or punish interventions. The nuclear deterrent may not be credible against what might be relatively low levels of threatened destruction and therefore other forms of tailored and scaleable deterrents will be needed (e.g. financial).

Reorganising and Realigning Defence Organisations

Dr E Seglie, Department of Defense, USA

REORGANIZING AND REALIGNING DEFENSE ORGANIZATIONS

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Washington, D.C, USA

Abstract

Many countries are in the process of implementing acquisition reform. The United States has changed many aspects of its acquisition process including the organization of its testing organizations, both at the Office of the Secretary of Defense level and in the Services.

This paper reviews these changes in the testing organizations and processes.

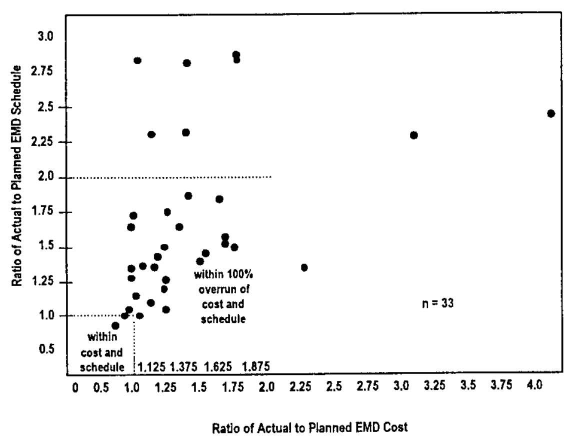
The Evolution of Defense Organizations

Napoleon is reputed to have said, "When all else fails, reorganize." It is ironic that the Western powers have all begun huge efforts to reorganize since the end of the Cold War. The Defense Systems Management College in the United States, as part of the International Defense Educational Agreement (IDEA) forum, studied the acquisition systems in the UK, Germany, France and the United States. Their first conclusion was that all the countries have experienced or are currently implementing some level of acquisition process reform. Why?

The reason they ascribe is the perception that it takes too long and costs too much to acquire new weapons systems.

Within the United States the evidence in favor of such a perception is supplied if we look at the cost and schedule overruns for programs. We asked the DSMC to investigate the details in those acquisition programs for which the Director of Operational Test and Evaluation had to provide a report to Congress. These are major programs, for which the total program cost is over a Billion Dollars, often tens of Billions.

We can display the relative overruns by plotting on one axis the ratio of actual cost to complete the phase to the planned cost. On the other axis is the ratio of the actual time to complete the phase to the planned time. This study is of the final phase of acquisition, from the Milestone II decision (at which Demonstration, Validation, and Risk Reduction is over and Engineering and Manufacturing Development is authorized) to the decision to go to full-rate production, called Milestone III. If the program manager had succeeded in delivering what was promised at cost and on time, each ratio would be one, and the program would be represented as a program at the point (1,1). The actual plot for the programs is:



For those major acquisition systems that produced DOT&E reports to Congress, the average cost over run is 40% and the average schedule over run is 62%.

Some comments are in order.

For those of you who were raised on the management dictum that time is money, you might expect that the overruns should fall on the diagonal with cost overrun about the same as schedule overrun on a per cent basis. This appears not to be the case, but the deviation can be explained. For some programs, in particular those that gave evidence of problems early; the Congress will sometimes impose a cost cap. This puts an upper bound on cost. Difficulties in the program then appear as slowing the spend rate. What often happens in this case is that the program itself changes. For example the B-1 was produced within the cost cap but without a defensive electronics suite. This type of trade-off now goes by the rubric "Cost as an

Independent Variable" in the Department of Defense.

So this is the presenting condition for which a solution is to be found. Note that there might be two ways to solve this apparent problem. First is to get a better estimate at Milestone II of what the cost and schedule would actually be. The second is to try to contain the cost and schedule to meet the promised cost and schedule identified at Milestone II. Most of the reorganization within the U.S. Department of Defense has focused on the latter. We should note that most studies of the matter, a Defense Science Board Study in the late 1980's and a RAND Study, have indicated that the reason for the overrun is a very optimistic estimate of the technical difficulty of the project.

One can imagine the pressures on programs to be optimistic it all the estimates. There is competition among the bidders when the programs request proposals for contractors. There is competition among programs for continued funding even after the program begins.

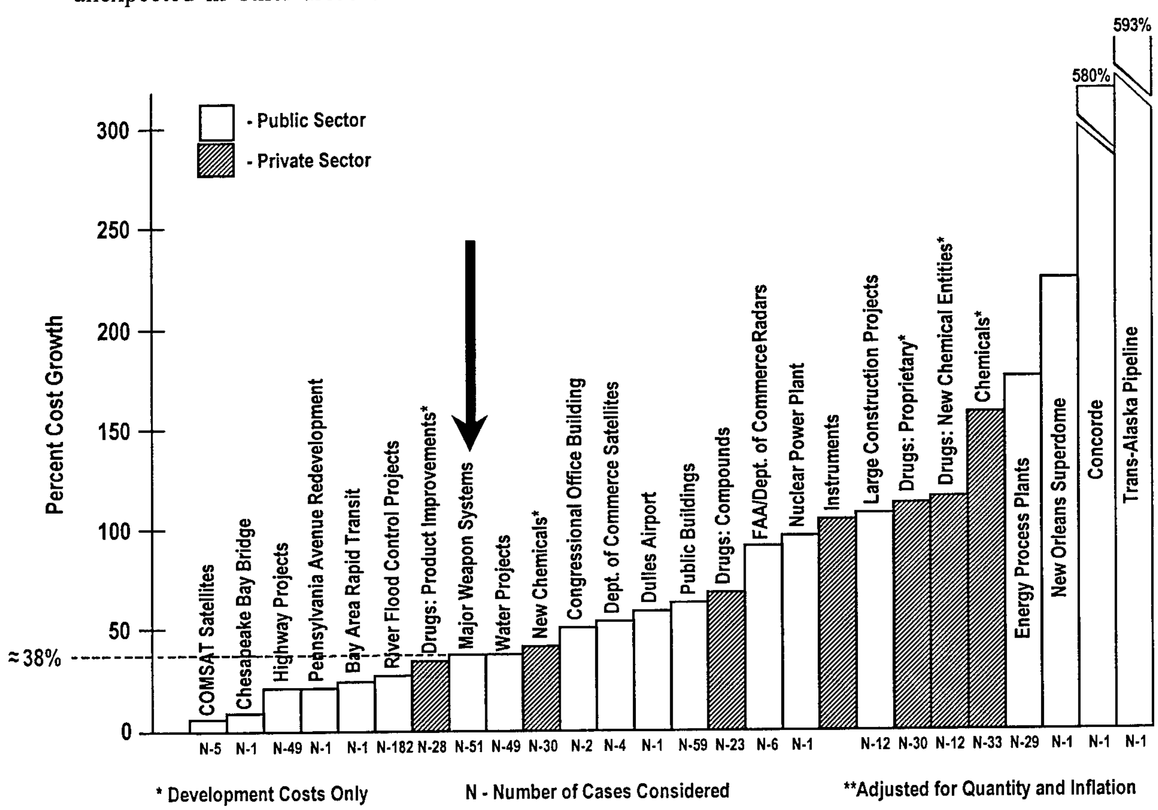
These are not pressures that would be unexpected in other areas of human endeavour where the project is large. In fact performance of such large programs has been analyzed.

This study of pre-1985 projects has about the same cost overrun as the post 1983 programs in the acquisition study.

The Different Organizations in US Defense

The organizations that had a stake in testing and Defense in the U.S. include:

- the Congress,
- the Director, Operational Test and Evaluation,
- The Undersecretary of Defense for Acquisition, Technology and Logistics (and at the time within that organization a Director for Research and Engineering and under the DDR&E a Director for Test, Systems Engineering, and Evaluation. One of the major changes was the disestablishment of the later office.) In the mid-80s, the Congress established a second T&E office within the Office of the Secretary of Defense that provided a different kind of oversight of the Army/Navy/Air Force Services from the first



office. It was established at the Assistance Secretary level to provide an independent operational T&E assessment prior to initiating production of any weapon system.

- The Services (Army, Navy, Marines and Air Force).

Within each Service there is an acquisition element and a testing element. Each of these has undergone some change. Probably the Army has done the most reorganizing. (The Army reorganization was the model for the recommendations for change made by the Defense Science Board.)

The Game-Theoretic Approach to Information (A National Academy of Sciences review of Test and Evaluation)

The evolution of institutions in DoD Operational Testing was studied in a game-theoretic model by members of a National Academies of Science panel that reviewed testing and acquisition for the Department. The model is of persuasion games in which an interested party (the agent) possess information regarding the state of nature and attempts to influence a decision-maker by selectively providing data.

Even under the assumption that the agent never makes an incorrect report, the agent may make reports that range from entirely uninformative to absolutely accurate. Early work showed that an equilibrium exists in which the decision maker resolves to ignore all reports and the agent makes only uninformative reports.

The model was extended to consider the case in which the agent can choose whether to become informed. When disclosure is mandatory, the agent may choose not to acquire information, and to claim ignorance (or use some other basis for claims).

The next stage of the game is for the decision-maker to take a stance of extreme scepticism on any claim of ignorance by the agent. The agent can counter if the cost of acquiring information is a privately-held information by the agent. Then claims about the cost of acquiring information can give credibility to the claims of ignorance by the agents. The notion of cost is here a general one and you can consider cost to include time. Thus the claim that it would take too long to acquire information is equivalent to the claim of excessive cost to acquire information.

Secretary of Defense Initiatives with respect to Test and Evaluation

As recommended by both Secretary Cohen and Secretary Perry, early involvement by operational testers provides early feedback to help acquisition programs address operational issues. As the Undersecretary of Defense for Acquisition Technology and Logistics (USD(A,T&L)) explained in a letter to the chairmen of the four Defense Committees, "I have advocated for many years that serious testing with a view toward operations should be started early in the life of a program. Early testing against operational requirements will provide earlier indications of military usefulness. It is also much less expensive to correct flaws in system design, both hardware and software, if they are identified early in a program. Performance-based acquisition programs reflect our emphasis on satisfying operational requirements vice system specifications."

To implement these policies, the Secretary of Defense decided to disestablish the office of Director, Test, Systems Engineering and Evaluation (D,TSE&E) within the Office of the Under Secretary of Defense for Acquisition and Technology, and move the following responsibilities to DOT&E:

- Central Test and Evaluation Investment Program.
- Joint Technical Coordinating Group for Munitions Effectiveness.
- Joint Technical Coordinating Group on Aircraft Survivability.
- Threat Systems Office.
- Precision Guided Weapons Countermeasure Test Directorate.
- Test and Evaluation Independent Activities.

The Secretary further directed that DOT&E: (1) exercise no responsibility with respect to Developmental Test and Evaluation of a defense acquisition program, except to advise those who do have such responsibility; (2) ensure that all contractor support is consistent with limitations of 10 U.S.C. 2399; (3) ensure that all actions taken are without regard to whether the particular range or equipment is used for DT&E

or OT&E; and (4) ensure that no action is taken that creates a conflict, potential conflict, or appearance of conflict of interest with respect to DOT&E's role which is independent of DT&E.

Oversight of developmental tests remains in USD(A,T &L). Joint Test and Evaluation (JT&E) also remains in USD(A,T&L). This activity was considered a special case because, while JT&E projects are not acquisition projects in and of themselves, they should help identify needed acquisition programs. However, the JT&E program was specifically chartered to provide a mechanism for joint operational tests that support the Commanders-in-Chiefs (CINCs) and the Services in developing more effective ways of employing fielded systems in a joint operational environment. To retain an operational test focus, the Secretary has determined that JT&E projects will be jointly chartered by the Director, Strategic and Tactical Systems (D,S&TS) within USD(A,T&L) and DOT&E. Also, as in the past, DOT&E will approve all JT&E program test plans jointly with D,S&TS. The Joint T&Es are reviewed in the main body of this report.

The Secretary also directed that DoD Directive 3200.11, "Major Range and Test Facilities Base (MRTFB)," be revised appropriately to reflect the realignment of responsibilities to reflect that DOT&E will establish policy for and composition of the MRTFB, and plan, program, and budget for the Central Test and Evaluation Investment Program.

In addition, the DOT&E charter (DoD Directive 5142.1) is being updated to reflect these changes.

After reorganization last year we hope for numerous benefits to the Department of Defense's T&E oversight role such as:

- A single voice to the Congress on matters of T&E policy, oversight and budget defense
- A single voice of oversight to the military departments of the Army, Navy and Air Force
- A single point of focus for test range modernization and T&E technology leadership

A Defense Science Board study is underway that will recommend to the Congress what more needs to be done to improve the efficiency and productivity of the T&E infrastructure operations. This study is scheduled to report out to the Congress in August, but it is likely that their recommendations will be in line with those reported out last year by the first DSB study group, such as:

- Start T&E planning early—very early
- Make T&E part of the acquisition process—not adversarial to it
- Consolidate DT and OT
- Provide joint test leadership
- Fund modeling and simulation support of T&E in program budgets
- Maintain independence of evaluation process while integrating all other activities
- Establish range ownership and operation structure separate from the Service DT/OT organization

Conclusion

For those of you who must reorganize and wish it to be successful, I would suggest that you hire a game theorist and social anthropologist. The Social anthropologist will work out the reward system for players in the game. Not as it is supposed to be, but as it really is. And the game theorist should be able to tell you how the rules and reorganization will be "played" within that reward system.

The Role of Test and Evaluation: A US Air Force Perspective

Brig-Gen W D Pearson, HQ Air Force Material Command, USA

The Role of Test & Evaluation: A United States Air Force Perspective

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Abstract

This paper discusses the United States Air Force perspective concerning the role that Test and Evaluation (T&E) plays in the United States (U.S.) defense acquisition process. For the U.S. Air Force, T&E is clearly an integral part of the acquisition process, and is involved in every phase from concept exploration to production. By supplying timely, accurate, and affordable information, the T&E community provides the Program Manager with the information needed to make decisions critical to the success of the program.

This paper also emphasizes how Air Force Materiel Command (AFMC) conducts developmental test and evaluation (DT&E), which along with operational test and evaluation (OT&E), are the two principal types of T&E employed by the U.S. Air Force. Key to the manner in which AFMC conducts DT&E is the constant effort to operate in a more cost-effective and time-efficient manner, while never forgetting that it is a military organization whose primary mission is to support the warfighter.

Introduction

Good afternoon. Considering the ability of this forum to draw so much talent from the international T&E community, I consider it a great privilege to be here speaking to you today. I would like to thank the Royal Aeronautical Society and the International Test and Evaluation Association (ITEA) for organizing this forum and for inviting me here.

Before I begin my formal remarks, I would first like to start with a short video clip that highlights the immense aerospace power that the U.S. Air Force brings to the battlefield. Many elements are necessary to build an airforce of this magnitude, and I am especially proud of the critical role that the U.S. Air Force T&E community has had in making possible the awe-inspiring weapon systems you will see in this video.

The world of U.S. Air Force T&E is fascinating and dynamic, and at times even frustrating, but in the brief time I have to speak, I want to give you some insight on the U.S. Air Force's philosophy concerning T&E, and the manner in which we use it to help build some of the finest weapon systems in the world. Specifically, I hope to be able to convey to you this morning that for the U.S. Air Force, T&E is an integral part of the acquisition process. The timely, accurate, and affordable information provided by the T&E community allows the Program Manager, also known as the Single Manager, to make critical lifecycle decisions. In addition, I want to emphasize that in today's environment of acquisition reform, which rightly seeks to acquire weapon systems "better, cheaper, and faster," the need for T&E is just as critical as ever. In fact, as many program managers can tell you, there is probably no "better, cheaper, and faster" way to jeopardize your program than to neglect the requirement for adequate testing.

Overall Role of U.S. Air Force T&E

When discussing the role that U.S. Air Force T&E plays in the procurement of weapon systems, it is crucial to point out that in the U.S. defense establishment, we make a significant distinction between DT&E and OT&E. How does DT&E differ from OT&E, and what role do they play in the procurement process? Quite simply, the U.S. Air Force uses DT&E to learn and confirm, that is, to learn about the system's capabilities, and to confirm that the system performs according to the specifications. With this knowledge, the Single Manager can evaluate the program for risk and determine the technical challenges that must be addressed to keep the program on track. Since AFMC is responsible for developing and acquiring the U.S. Air Force's weapon systems, it is AFMC that conducts DT&E.

On the other hand, the U.S. Air Force uses OT&E to answer two fundamental questions. First, given a realistic environment, can the warfighter use the system to accomplish the mission? Second, given the same realistic environment, can the warfighter support and maintain the system? In the language of U.S. Air Force T&E, the first question measures operational effectiveness, while the second measures operational suitability. The clear distinction we make between DT&E and OT&E

recognizes the fact that while a weapon system may meet all the design specifications, it may still fail to accomplish the mission. Just as important, U.S. law dictates that the agency responsible for OT&E must be independent of the command that develops the weapon system. Thus, while AFMC is responsible for DT&E, the Air Force Operational Test and Evaluation Center (AFOTEC) carries the OT&E mission for the U.S. Air Force.

T&E is Integral to the Acquisition Process

One of the main points I want to emphasize is that for the U.S. Air Force, T&E plays an integral role in the acquisition process. Perhaps Dr Jacques S. Gansler, Under Secretary of Defense for Acquisition and Technology, captured the U.S. Air Force T&E perspective best when he addressed the ITEA Symposium last year. In his address Dr Gansler stated

> "We must produce our weapon systems on greatly reduced cycles . . . with greatly enhanced performance . . . at greatly reduced cost. Testing throughout the development process is a key to our success in these objectives. This puts our testing community . . . as an integral part of the acquisition team."

The whole idea is that for the U.S. Air Force, T&E isn't something that comes at the end of the acquisition process, that is, it isn't a type of pass/fail exam or a process of inspecting a finished product for quality. Rather, the T&E community should be involved from the very beginning of the acquisition cycle, and the timely, accurate, and affordable information T&E provides to decision makers is critical to the success of the program.

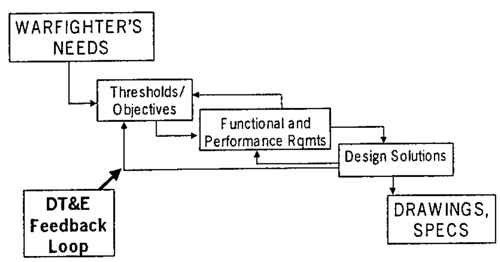
DT&E Role in Acquisition Process. Let's first discuss the three primary roles that DT&E plays in the acquisition process, and why these roles are so valuable to the Single Manager and other decision makers. First, DT&E acts as the essential feedback loop within the systems engineering process. Second, it provides the Single Manager with an independent perspective of the system. And finally, DT&E serves as a bridge between the technical community that designs the system, and the operational community, which must use that system.

Within the U.S. acquisition community, we make extensive use of the systems engineering process (Figure 1), which is an iterative problem-solving process that translates the warfighter's needs into performance thresholds and objectives. Thresholds represent the minimum capabilities that the weapon system must achieve, while objectives represent the desired capabilities. These thresholds and objectives are then used to determine functional and performance requirements, which then translate into design solutions, and eventually end up as drawings and system specs. This process is repeated constantly as the design system evolves from models to components, and then to complete systems.

What is DT&E's role in the systems engineering process? Clearly, DT&E acts as the essential feedback loop. In fact, DT&E is the only way to insure that the design meets the warfighter's operational needs as originally identified in the thresholds and objectives. If a program does not have adequate DT&E, the

Figure 1

Systems Engineering Process



Single Manager will simply not be able to verify that the system meets the warfighter's requirements. To the extent that the Single Manager cannot verify that the system meets the warfighter's requirements, he will incur a corresponding increase in risk associated with fielding the system. The system may not perform as designed and could even end up having disastrous results. Therefore, the Single Manager should clearly recognize the value of DT&E as a primary tool for risk reduction. In addition, the valuable data that DT&E provides to the Single Manager will allow him or her to have a rationale, informed basis for making tradeoffs between cost and performance.

Secondly, DT&E, and specifically U.S. Air Force DT&E, as opposed to contractor DT&E, provides the Single Manager with an objective and independent assessment of system performance. This independent assessment is

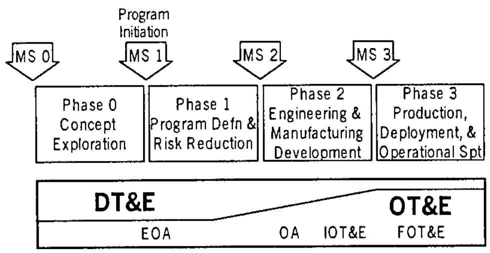
absolutely critical to the success of any program. In this sense, the U.S. Air Force DT&E community acts as the Single Manager's trusted agent, providing him or her with independent reporting on system performance and spec compliance, and insuring that the so called "bad news" will not get buried or suppressed. This degree of independence and objectivity also gives the U.S. Air Force DT&E community a great degree of credibility with Operational Test Agencies (OTA), such as AFOTEC. Thus, when the DT&E community certifies that a system is ready for OT&E, the OT&E community knows it can trust their assessment. This credibility also means that the OT&E community can trust a DT&E assessment to focus operational testing on specific problem areas.

Lastly, U.S. Air Force military DT&E testers typically possess operational experience and therefore are able to speak the language of both the engineer and the operator. In this sense, the U.S. Air Force DT&E test community has a unique understanding of both the design constraints and the user's requirements. Thus, the Single Manager has a unique and vital resource that he can and should use to insure the success of his program.

OT&E Role in Acquisition Process. Moving to the role that OT&E plays in the acquisition process, it is important to reemphasize that the U.S. Air Force involves the OT&E community from the very beginning of the acquisition process (Figure 2). Early in the program, the OT&E community helps formulate useful and well-defined weapon system program requirements. Prior to Milestone (MS) II, that portion of the acquisition cycle that essentially deals with concept exploration and preliminary design, the U.S. Air Force operational test community will conduct Early Operational Assessments (EOA) to forecast and evaluate the potential operational effectiveness and suitability of the weapon system during development. After MS II, in which the program moves into a detailed design phase, the operational test community conducts Operational Assessments (OA) to evaluate the system's potential to meet mission requirements, and to help support a decision to begin initial production, known formally as a low rate initial production (LRIP) decision. With the production of the first few production articles, the operational testers begin Initial OT&E (IOT&E), which is conducted on the LRIP articles to insure that the program is ready to enter full-rate production. After MS III, or the full-rate production phase, the operational test community conducts follow-on OT&E (FOT&E) to confirm corrections of deficiencies noted in IOT&E, and to evaluate major modifications to the system.

Figure 2

T&E and the Acquisition Process



How AFMC conducts DT&E.

It is now time to turn our attention to the manner in which AFMC actually carries out DT&E for the U.S. Air Force. Some of the concepts I will discuss, such as Single Face To the Customer (SFTC) and Responsible Test Organization (RTO) are unique to the way the U.S. Air Force conducts DT&E. Other concepts, such as the Combined Test Force (CTF) and Combined Developmental Test/Operational Test (DT/OT), apply to all U.S. military services. Of course, in these days of reduced budgets and shrinking forces, AFMC is constantly seeking new ways to support the warfighter in a more cost-effective and time-efficient manner. But regardless of how we conduct DT&E for the U.S. Air Force, I want to stress that AFMC is first and foremost a military organization. While we strive to insure our decisions make sense from a business perspective, there are times when the "commercial or business solution" will simply not apply. The need to accomplish the mission will always override the desire to implement practices that make sense from a business perspective only.

Single Face To the Customer (SFTC) Concept. We all know that the world of T&E is a specialized discipline, and although it is clearly critical to the success of any acquisition program, the typical Single Manager does not have the in-house expertise to take care of all his or her T&E planning needs. For that very reason, the U.S. Air Force has established the SFTC office, which serves as the first stop for all Single Managers, providing comprehensive, top-level T&E planning from a non-geographic or

test center perspective. I should point out that the SFTCs also serve as the initial point of contact for U.S. contractors as well. We have five SFTC offices, which correspond to the five test mission areas: Airframe-Propulsion-Avionics (APA), Armament/Munitions (A/M), Command and Control (C2), Electronic Warfare (EW), and Space. In a very real sense, the SFTCs are an extension of my headquarters staff, and are physically located at the AFMC test centers where the predominance of T&E resources related to that specific mission area resides.

Each of the SFTC offices are staffed with knowledgeable and experienced personnel who stay current on the latest U.S. Air Force T&E instructions, directives, processes, and trends. In addition, the staff also has access to operations, range, logistics, and program personnel to provide a full spectrum of technical and program support. From a mission area perspective, the SFTCs are able to provide the Single Manager with information on measurement facilities (MF), hardware-in-the-loop (HITL) facilities, system integration laboratories (SIL), installed system test facilities (ISTF), and open air ranges (OAR) throughout the Department of Defense (DoD). And each SFTC is well equipped to identify and recommend the optimum combination of test resources that are available throughout the U.S. Air Force and DoD. Whether developing a new system, or working a major modification, upgrade, or product improvement program, the Single Manager can tap the appropriate SFTC for initial T&E planning.

Responsible Test Organization (RTO) Concept. Once the initial T&E planning is underway, one of the most important duties of the SFTC is to provide a prioritized list of recommended Responsible Test Organizations, or RTOs, to the Single Manager. What exactly is an RTO? Essentially, an RTO is the government agency responsible for the oversight of the planning, safety, conduct, and reporting of developmental test programs. Notice that I said *government* agency, and that "conducting tests" is not the exclusive right of the RTO. Many times only the contractor has the expertise to actually conduct the test. But in keeping with the philosophy that DT&E is an inherently government responsibility, only a government agency can be the RTO, not the contractor. Typically, RTOs are test organizations within U.S. Air Force test centers, Air Logistics Centers, or other service test organizations. During the development of a system, a program may need several RTOs for different phases of the program, but there will only be one RTO for a specific phase at any given time. As the Director of Operations for AFMC, only I have the authority to formally designate a specific organization as the RTO, though I make this decision in collaboration with the Single Manager and the commanders of the test organizations. Once I designate the RTO, the SFTC transfers all DT&E planning responsibility to the RTO.

Combined Test Force Concept (CTF). As the agency responsible for the detailed-level planning of the Single Manager's test program, the RTO is fully expected to use the CTF concept to the greatest extent possible. The CTF, which is comprised of contractor, DT&E, OT&E, and operating command personnel, can be located at one primary test site or distributed across multiple test sites, and seeks to get the biggest T&E "bang" for the increasingly limited "buck" available for testing. By sharing assets, analysts, support staff, and test events, the seemingly separate test objectives of the contractor and U.S. Air Force testers, both DT&E and OT&E, can be combined to realize savings in both time and money. Combined DT/OT is perhaps the most obvious example of how the CTFs save time and money. An example of combined DT/OT could be a prototype free-fall munition that is released from a fighter aircraft at operational employment conditions instead of from a static stand, thus satisfying both DT and OT objectives.

The advantages of the CTF are many and include a decrease in the time required for testing, and therefore a shortened acquisition life cycle, elimination of redundant activities and a corresponding savings in cost, and early involvement of OT&E personnel during system development. Early involvement of OT&E personnel increases their familiarity with the system and permits them to convey operational concerns to the developer in time to allow changes in system design.

Before leaving this topic, I want to emphasize that the CTF, and especially the push for combined DT/OT, is not a mixing and matching of DT/OT objectives. The CTF fully realizes the importance of recognizing separate DT and OT objectives where necessary. Clearly, the requirement for the DT&E and OT&E communities to maintain a degree of independence resides not in collecting separate test data, but in the independent analysis and

reporting of that test data. While not forgetting that there must always be a phase of dedicated OT&E, the CTF concept allows the operational testers to get involved early where they can have an important impact in highlighting concerns at a time when they can be more easily corrected.

T&E and Commercial-Off-The-Shelf (COTS)/Non-Developmental Items (NDI). In many ways, the U.S. defense community has greatly benefited from COTS/NDI. Through COTS/NDI, we have greatly reduced the time to field a system, saved scarce R&D funds, and incorporated state-of-the-art technology much sooner. On the other hand, COTS/NDI presents certain challenges as well, especially from a T&E perspective. Typically, COTS/NDI acquisitions are used in an environment different from the one for which they were originally designed. Secondly, engineering and test data is often not available. Therefore, as the acquisition community turns to COTS/NDI because of its genuine advantages, it is important that the T&E community help the Single Manager understand the need for adequate testing. More importantly, perhaps, the T&E community itself must formulate a strategy for better integrating COTS/NDI into the T&E process. I think we can all agree that COTS/NDI is an area that has presented challenges that we in the T&E community have not been able to answer completely, but one that we cannot ignore.

International Test and Evaluation Programs. Given the international audience here today, I think it especially appropriate to discuss the immense benefits that all U.S. military services have reaped from the international T&E programs we have with our allies. For example, the Foreign Comparative Test (FCT) program allows us to evaluate a foreign nation's weapon system or technology in terms of its potential to meet a requirement for our own military services. As U.S. testers work with the test community from other nations to evaluate the existing test data and to validate test data collected during our evaluation, the U.S military services not only save T&E funds, but also procure weapon systems already developed and in use by our allies. To cite only a few examples, under the North Atlantic Treaty Organization (NATO) Comparative Test Program, the U.S. has procured the Norwegian Penguin missile, a United Kingdom-designed minehunter, and a German mine reconnaissance and detection system.

Going beyond FCTs in terms of international T&E cooperation, the U.S. testing community has also has worked closely with our NATO allies on several cooperative programs. For example, during the U.S. and NATO Airborne Warning and Control System (AWACS) Electronic Support Measures (ESM) program, which greatly improved enemy identification and combat surveillance capabilities, both U.S. and NATO E-3As were used as test aircraft in a combined DT/OT program. A Joint Test Force (JTF), comprised of members from the U.S. and NATO test community, conducted testing in both the U.S. and European theaters. In an example that directly impacted our recent conflict in Kosovo, testers from the U.S., Belgium, Denmark, the Netherlands, and Norway worked together and at an accelerated schedule to upgrade the European Participating Air Forces' (EPAF) F-16s. Taking the EPAF F-16s from 1970s to 1990s technology, the upgrade allowed the aircraft to operate with LANTIRN targeting pods and laser-guided bombs, thus providing our European allies with increased combat capabilities in direct support of vital NATO missions during Operation ALLIED FORCE. In today's world of coalition warfare, where weapons standardization and interoperability within NATO are increasingly important, these cooperative programs are critical.

Further proof of the advances the U.S. and its NATO allies have made in the area of international T&E cooperation can be seen by the numerous agreements the U.S. now has with France, Germany, and the United Kingdom to accept each country's T&E data, and thereby avoid redundant testing. Along these same lines, cooperative efforts by France, Germany, the United Kingdom, and the U.S. have resulted in International Test Operations Procedures (ITOPs), documents containing mutually acceptable standardized test procedures. The ITOPs include state-of-the-art test procedures, and their use ensures high quality, efficient, accurate, and cost effective testing. The latest effort by the ITOPs community has centered on standardizing Modeling and Simulation (M&S) test procedures, an area that has become increasingly important to all testers worldwide. The success of ITOPs can be seen by the fact that non-signatory allies such as Israel, Sweden, and Spain routinely use ITOPs in developing their military systems. In summary, the ITOPs program is yet another excellent example of how the U.S. and NATO test communities are working together to shorten acquisition timelines, minimize duplicate testing, improve

interoperability of U.S. and allied equipment, and exchange advanced test technology.

Funding DT&E. I think it is important to finish my discussion on the manner in which AFMC conducts DT&E by discussing how AFMC actually funds DT&E. U.S. Air Force DT&E is funded by a combination of customer (or direct) and institutional (or indirect) funding sources. Customers pay the direct costs such as direct labor, flying hours, test facility costs, and a proportional share of certain other costs (like range use costs). We use institutional sources to pay for our military personnel, center staffs, base support, indirect test costs, and to sustain our test infrastructure. This method of funding seems to strike the right balance--affordable testing for our customers while sustaining our extensive test infrastructure. This balance between institutional and customer sources is common to all members (Army, Navy, and Air Force) that operate under the Major Range and Test Facility Base designation.

With acquisition reform, we see more DoD contractors making the important decisions of whether or not to test, and where to test. These decisions greatly impact our DT&E capabilities. We have certain test capabilities that are national assets, assets that we must maintain regardless of whether or not there is a near-term demand for the capability. Of course, it's best if we have customers paying our testers' salaries. However, if the contractors decide to test somewhere else, or not test at all, we still have to maintain a cadre of experienced testers. In these circumstances, our goal is to keep the minimum number of testers needed to maintain the capability. In recent years we have sought to reduce the cost of maintaining this cadre by cross-training our testers so that they are multi-skilled and able to support more than one test capability. We have reduced the number of test support aircraft and constantly address the size and capability of the infrastructure we are tasked to maintain. The bottom line is we are continuously looking to balance the need to maintain critical test capabilities with the desire to operate in a cost-efficient manner.

Summary

Let me conclude by reemphasizing some of the key themes I have discussed today. First, it should be clear that T&E plays an integral role in the acquisition process. T&E provides the Single Manager with the critical information he needs to make the key decisions necessary for a successful program. And secondly, through our SFTCs, RTOs, and CTF concept, AFMC strives to conduct T&E in the most effective and efficient manner possible given our limited resources. However, even as we do our best to make smart business decisions in implementing T&E, we will never let our desire to run an efficient T&E business override our need to support the warfighter. Thank you.

Glossary

AFMC - Air Force Materiel Command
AFOTEC - Air Force Operational Test and Evaluation Center
A/M - Armament/Munitions
APA - Airframe-Propulsion-Avionics
AWACS - Airborne Warning and Control System

C2 - Command and Control
CTF - Combined Test Force

DoD - Department of Defense
DT&E - Developmental Test and Evaluation
DT/OT- Developmental Test/Operational Test

EOA - Early Operational Assessment
EPAF - European Participating Air Forces
ESM - Electronic Support Measures
EW - Electronic Warfare

FCT - Foreign Comparative Test
FOT&E - Follow-On Operational Test and Evaluation

HITL - Hardware-In-The-Loop

IOT&E - Initial Operational Test and Evaluation
ISTF - Installed System Test Facility
ITEA - International Test and Evaluation Association
ITOPs - International Test Operations Procedures

JTF - Joint Test Force

LRIP - Low Rate Initial Production

MF - Measurement Facility
MS - Milestone
M&S - Modeling and Simulation

NATO - North Atlantic Treaty Organization

OA - Operational Assessment
OTA - Operational Test Agency
OT&E - Operational Test and Evaluation

R&D - Research and Development
RTO - Responsible Test Organization

SFTC - Single Face To the Customer
SIL - System Integration Laboratory

T&E - Test and Evaluation

U.S. - United States

The Federated Laboratory Operational Concept

J Miller, US Army Research Laboratory, USA

THE FEDERATED LABORATORY OPERATIONAL CONCEPT

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Abstract

The Army Research Laboratory (ARL) has implemented an innovative program for partnering with the private sector called the Federated Laboratory (FedLab). Driven by the requirement to develop technology in areas where the private sector has both the technical lead and a substantial investment, ARL decided to use a relatively new instrument, the Cooperative Agreement, to fund consortia of industry and universities to work in partnership with government researchers. This innovative program has been under way for four years. Strong collaborative relationships have been established with these consortia of industry and university partners, and they are pursuing high-quality science and technology. The collaborative nature of these partnerships has greatly facilitated not only the transfer of knowledge within FedLab, but also the transfer of innovative technologies to Army and other customer applications. The program has been recognized by the Office of the Vice President with a Hammer Award as an example of reinventing the way the government does business. The Army and ARL intend to build on these programs and initiate a new expanded FedLab that will produce key technologies to enable the new Army Vision.

Introduction

As the Army's corporate laboratory and a member of the Army Materiel Command (AMC) team, the U.S. Army Research Laboratory (ARL) provides materiel readiness through innovative technology. Its mission is *to provide the Army with the key technologies and analytical support that are necessary to ensure supremacy across the spectrum of military operations.* ARL conducts basic and applied research through a variety of arrangements with external organizations, including industry, academia, foreign laboratories, U.S. National Laboratories, and other Service laboratories. ARL also conducts in-house research and analysis with a staff of approximately 1250 scientists and engineers. ARL's primary customers are the AMC Research, Development, and Engineering Centers (RDECs), Army Program Managers, and the Army Battle Labs.

ARL has a long history of establishing partnerships with external organizations to seek the best solutions and technologies for Army needs. Typically, these partnerships are accomplished via contracts, grants, cooperative research and development agreements (CRADAs), and memoranda of agreement. Over the past four years, ARL has developed a unique series of public-private partnerships through the use of Cooperative Agreements with consortia of industry and university partners. These partnerships have formed the Army's Federated Laboratory (FedLab) initiative.

Why FedLab?

In the mid 1990's, it became apparent that for the Army to maintain dominance on the future battlefield, information technology would be essential. Moreover, it was also clear that much of this technology was developing at an extremely rapid pace, primarily driven by private sector investments in research. Although this development is essential to Army needs, it was generally not directly applicable, since the Army often requires technology to operate in conditions and environments different from the typical commercial environment (usually more severe). For example, consider cellular communication on the battlefield. Whereas commercial sector technology is based on a fixed (and unstressed) infrastructure, an Army application would require networks and infrastructure that are highly mobile, that can be reconstituted on a nearly continuous basis as nodes move in and out of the network, and that can survive in an active battlefield environment. As a result, additional research beyond ongoing private sector research was required to fully address Army requirements.

The challenge for the Army was to develop a mechanism whereby Army-unique research could be coupled with ongoing private sector research so that the Army could take full advantage of commercial technologies at the same rapid pace that they were being applied commercially. It clearly did not make sense to attempt to duplicate the private sector's capability in-house. However, in-house research that focused on Army-unique problems was essential to ensure proper coupling of the Army and private sector research and to transition commercial research to Army applications.

The FedLab program was devised by the Army and ARL to address this critical need. Through a relatively new instrument known as a Cooperative Agreement (not a CRADA), ARL funded public-private partnerships with universities and academia. The Cooperative Agreement allowed ARL to form true partnerships with the private sector to jointly plan and execute research and (most importantly) to transition the technology developed to Army applica-

tions. (In contrast, more traditional contractual or grant arrangements require an "arm's length" relationship with the vendor.) The FedLab program capitalizes on the strong lead the commercial sector has in information technology, augmenting it with innovative research from the academic sector and focused research from government laboratories, to accomplish military-specific objectives.

What is FedLab?

FedLab has transformed ARL into a geographically distributed virtual laboratory consisting of consortia of industry and university partners augmenting the core in-house research program. Under ARL leadership, the private sector research program is tightly integrated with ARL in-house research to focus on Army requirements and applications. Each consortium consists of industry and university members with an industry lead. Scientists and engineers from industry partners provide their knowledge of ongoing commercial product research and development, as well as a focus on technology transition opportunities. University members bring their commitment to cutting-edge research and an education focus, which provides a constant stream of fresh innovative thinking in the form of graduate students and their professors. The industry partners harvest the research efforts of the universities for insertion into products. Besides contributing their own unique research skills, ARL researchers keep the program oriented towards Army-specific problems.

After an extensive competition, ARL signed Cooperative Agreements with three consortia and provided funds for industry and academic partners to conduct research with ARL in support of Army needs. The use of Cooperative Agreements provides ARL the flexibility to react to newly discovered research opportunities, as well as to evolving Army needs for technology. Cooperative Agreements also allow ARL researchers to work closely with private sector partners in planning and executing joint research. Virtually every research project or task within the FedLab program is jointly planned and executed by a Principal Investigator from ARL and one from at least one industry and university partner. The Cooperative Agreement allows a fully integrated management approach to program planning and execution in FedLab. It also acts as a five-year roadmap for the program: Research goals and objectives are developed jointly by ARL and the consortium and documented in the Cooperative Agreement.

Each Consortium is managed by a Consortium Management Committee (CMC), which is chaired by the industry lead and consists of representatives from each private sector partner. All consortium activities are managed through the CMC, which typically meets quarterly. The CMC also approves yearly research plans for submission to and final approval by the ARL Cooperative Agreement Manager (CAM), who participates in the CMC in an *ex-officio* capacity. These Annual Program Plans (APPs) document detailed research goals for the year. The CAM ensures that the consortium research is properly integrated with the overall ARL research program. This integrated approach to program planning and execution ensures that research performed by the private sector partners augments and effectively extends that of the core ARL in-house program.

Several innovative approaches have been adopted in FedLab to encourage and enhance collaboration among the private sector partners and government in-house researchers. These include provisions for a collaborative environment using web-based technologies and video teleconferencing, extensive staff rotations of ARL and consortia researchers, and educational initiatives.

The consortia have established secure web-based environments for collaborative research. This allows consortium and government researchers to post and share research results, including ongoing research, published papers and reports, annual research plans, calendars of events, discussion groups, and interactive files and data. For example, multiple researchers from several different organizations collaborate in the development of advanced image-processing algorithms by sharing databases and algorithm modules over the web. In addition, extensive use of video teleconferencing has enabled researchers to conduct informal meetings, seminars, and lectures remotely as a means of sharing information and enhancing collaboration.

Both long- and short-term staff rotations have been used to enhance collaboration among research partners and ARL. Over 40 researchers have been on long-term rotation, with many more on short-term assignments. This has greatly facilitated the flow of ideas and research results. In many cases, opportunities for collaboration were discovered only after researchers spent time working in other laboratories. For example, a collaboration combining acoustic sensor research at ARL, self-power generation research at MIT, and signal processing at Lockheed Martin resulted in a novel capability to monitor the soldier's physiological condition without the need for batteries. This opportunity resulted from a short-term rotation of MIT researchers at ARL, during which time they discovered research at ARL complementary to ongoing research at MIT. This and other

similar cases have resulted in many successful transfers of technology among partners and to Army and other external customers.

The FedLab partnerships have provided a significant source of educational opportunities for ARL researchers. Consortium members have established a variety of formal and informal education programs including fellowship programs leading to advanced degrees, short courses in critical technology areas relevant to the FedLab research areas, and lectures, seminars, and workshops in FedLab research topics. In addition, a symposium is held annually at which ARL and consortium researchers present research accomplishments over the past year via presentations, posters, and technology demonstrations. These annual symposia also provide an opportunity to show how the work of the three consortia is being integrated towards the overall FedLab goal of fostering the digitization of the battlefield.

Current Programs

The Cooperative Agreements for the current ARL FedLab programs were awarded in January 1996. Three consortia were established: Advanced Sensors; Advanced Telecommunications & Information Distribution; and Advanced & Interactive Displays. Consortium membership ranges from 6 to 12 industry and university partners.

The *Advanced Sensors Consortium (ASC)* conducts research in support of the next generation of more affordable and more capable Army sensors for future combat systems, the individual soldier, and Army aviation. Research is grouped into the following major areas:

a) Multi-Domain Smart Sensors: Research aimed at developing technology for common-aperture, multispectral passive/active imagers that will achieve a major performance improvement compared to state-of-the-art infrared imagery systems.

b) Multi-Sensor Fusion Automatic Target Recognition: Research focused on the combination of information from multiple sensors to provide improved recognition performance.

c) Radar: Research to enable the development of compact, affordable millimeter-wave radars and ultra-wideband radars for obscured target detection.

d) Signal Processing: Research to develop enabling technology for both low-power individual soldier applications and for compact high-density tactical signal processors.

e) Microsensors: Research focused on advancing technology for Army applications based on micro-electro-mechanical systems (MEMS) and other small, low-cost, low-power sensor devices.

In the past four years, substantial progress has been made in many of these areas, and technology products are beginning to transition from the Advanced Sensors consortium to various programs both in and outside the Army. Examples include multicolor infrared cameras and networked microsensors. High-performance multicolor focal plane arrays have been transitioned to Army and other DOD programs. Low-power signal processing techniques developed in FedLab are transitioning to unattended ground sensor and micro-robot sensor programs.

The *Advanced Telecommunication & Information Distribution Research Program (ATIRP)* is conducting research in mobile wireless communications in support of a more deployable, agile, and survivable force. Research is grouped into the following major areas:

a) Wireless Battlefield Digital Communications: Research focused on providing wireless digital communications in an integrated architecture for mobile warfighters.

b) Tactical-Strategic Interoperability: Research to provide seamless interoperability and management of heterogeneous networks.

c) Information Distribution: Research to provide automated information distribution from disparate sources on the battlefield with reliability, adaptability, and robustness.

d) Multimedia Concepts: Research to provide multimedia communications to enhance the situation awareness of the warfighter.

e) Defensive Information Warfare: Research to provide survivable and secure tactical networks and information warfare protection technologies.

The ATIRP consortium has successfully transitioned a number of advanced technologies to Army and other DOD customers. Examples include a mobile internetworking protocol for the Army's Warfighter Information Network testbed and technologies to enable reliable, robust underwater acoustic communications for Navy submarines.

The *Advanced & Interactive Displays Consortium* is conducting research in software, algorithms, and human factors required for the effective display and presentation of information and knowledge to warfighters on a broad variety of hardware platforms. Research is grouped into the following major areas:

a) Cognitive Engineering: Research in database management for battlefield visualization and planning, intelligent information processing for visualization, and course-of-action planning.

b) Perception-Based Display Formats: Research in improved multimodal human-computer interaction (including speech recognition, eye-tracking, three-dimensional audio, and other modalities) and augmented reality (the overlay and registration of real and virtual worlds).

c) Soldier-Centered Computer Interface: Research in the integration of new human-computer interaction modalities into systems for human factors evaluation and use.

The Advanced & Interactive Displays Consortium is successfully transitioning a number of research products to Army and other DOD programs. Several innovative decision aids have been transmitted to the Army Battle Labs for evaluation. Major elements of the multimodal integrated display testbed have been transferred to Army customers as well.

The three FedLab consortia have also jointly planned and executed research aimed at developing technologies for networks of low-cost unattended sensors. Research supporting networked microsensors includes low-power signal processing, sensor beamforming, point-to-point communications, network topology, and data and information display techniques. Research products developed through this collaboration have been evaluated in a series of field experiments in realistic environments. Much of this research is transitioning to an Army applied research program designed to demonstrate extended battlespace sensing for the warfighter.

Future Plans

The current FedLab programs will conclude in mid-2001. Based on the successes of these programs, it has been decided to initiate a new generation of public-private partnerships that build on the current FedLab programs. The new generation of partnerships will again focus on technologies where the private sector has a significant lead, and which can substantially improve the Army's ability to dominate the full spectrum of future military operations.

The Chief of Staff of the Army has outlined the new Army Vision and his intention to lead a transformation of the Army. The elements of this vision and transformation include making the Army more deployable, lethal, and survivable, as well as reducing its logistical footprint. The heavy forces must become more deployable and the light forces more lethal. It is widely recognized that technology will play a major role in achieving this vision, both in the near and far term, as the Army's Objective Force is developed and fielded.

The next-generation FedLab will address technologies essential to fully realizing this vision, again drawing expertise from the private sector where it has strong capabilities. These technologies include advanced sensors, advanced decision architectures, communications and networks, robotics, and power and energy.

Government participation in the programs will be broadened: other Army organizations, as well as other government agencies, will be able to participate through a Research Management Board (RMB) chaired by ARL. Other government agency participation on the RMB will provide these agencies the opportunity to influence the research programs, to identify other applications for technologies developed by the consortia, and (if appropriate) to provide funding to facilitate transition of those technologies to customer programs and applications.

Summary

The Army's Federated Laboratory program is a successful example of a true public-private sector partnership. Strong collaborative relationships among government, industry, and university researchers have been established and are leading to high-quality research and technology. The collaborative nature of these partnerships has greatly facilitated not only the transfer of knowledge within FedLab, but also the transfer of innovative technologies to Army and other customer applications. The program has been recognized by the Office of the Vice President with a Hammer Award as an example of reinventing the way the government does business. The Army and ARL intend to build on these programs and initiate a new expanded FedLab that will produce key technologies to enable the new Army Vision.

Creating Positional Advantage -
Strategic Vision, the Operational Art and Tactical Execution

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CREATING POSITIONAL ADVANTAGE --
STRATEGIC VISION, THE OPERATIONAL ART AND TACTICAL EXECUTION

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Abstract

The iterative process of anticipating the changing environment, acting on likely courses of action, and maintaining situational awareness to insure expectations remain aligned with reality lead an organization to early discovery of many of the roles and working practices required for success in a changing environment. This process also leads an organization into a cycle of continual change and the additional challenges that this creates.

Currently, the Defense Community is in a period of change known as the Revolution in Military Affairs (RMA). The RMA is the adoption of technology advancements to change the military operational model to meet the changing circumstances of the post-Cold War era, an era of reduced budgets, manpower reductions and increased commitments. In both military operations and defense business the demand for change is a constant. Managing this change over time is essentially the operational art and campaigning in its warfighting sense. One school of this period, the advocates of Network Centric Warfare, is studying the leading information age organizations to learn how these corporations have adopted information age concepts and technologies to leverage information and information technology (IT) to create competitive advantage.

In **Net Ready, Strategies for success in the E-conomy,** Amir Hartman and John Sifonis, have analyzed the experience of more than 400 companies involved in the Internet business revolution and developed the concept of Net Readiness®. They have defined the common characteristics found in varying degrees in all these corporations. These common characteristics, the pillars of Net Readiness®, are leadership, governance, technologies and competencies.

In the early 1990's Cisco Systems was a successful company providing the hardware and software that comprised 80% of the backbone of the Internet. However, there also were numerous challenges. The organization had grown 70% annually. Customer satisfaction levels were satisfactory, but stagnant, and it was becoming difficult to find enough skilled engineers to respond to customer queries and to service increasingly complex networks. To remain successful Cisco needed to find ways to keep up with the demands of the market place and the requirements of the individual customer.

Cisco's response to the continuing demand for change to meet these driving forces has brought it significant success.

In 1992 in response to its rapid growth and the opportunity for continued growth Cisco started development of an Internet business model -- the Global Networked Business model. This model uses the network to build interactive, knowledge-based relationships with customers -- e-commerce and customer service, with partners and suppliers -- supply chain management, and with employees -- workforce optimization. These solutions are Cisco Connection Online (CCO), Manufacturing Connection Online (MCO) and Cisco Employee Connection (CEC). The result of this network centric business model for fiscal year 1999 were net sales of $12.2 billion, $825 million in savings from Internet business processes, and a per employee productivity figure of $688,000 as compared to $250,000/employee in the closest industry vertical, other Internet companies. Additionally, once proven to be a successful model, the model itself became a source of growth

Admittedly not one hundred percent transferable, Cisco's success during the 1990's can provide an experienced-based insight for the T&E community into the process of preparing for the "Roles and Working Practices in the Changing Environment."

Introduction - The Budget, Business and Operational Challenges

Since 1989 both warfighting and Operations Other Than War have keep the troops in the field, consumed the service life of equipment and depleted operational stocks. We have seen large-scale efforts such as Desert Shield/Desert Storm, Bosnia and Kosovo, smaller scale peacekeeping missions in East Timor and Somalia, repeated deployments to festering trouble spots such as Sierra Leone and the Congo, and numerous humanitarian relief operations throughout the world.

Also, since 1989 the defense community has been in a period of continuous change. The changes have been in all aspects of defense -- budgets, manning, doctrine, organization, and business process. In general, the trend lines for the resource categories have been down, while the operational tempo, change, and consumption trend lines have been up. This has created a mismatch of commitment to resources.

In addressing the Australian problem, Dr. Allen Hawke, Secretary of the Australian Department of Defense succinctly stated the problem faced by many nations.

> "The irony of our professional military performance in East Timor is that it masks the reality we face. Australia's national security is challenged by a convergence of financial, management, planning and strategic pressures. The Australian Defence Organisation's ability to present a range of capability and military response options to government will be severely constrained if these combined pressures are left unchecked. This crisis, which has been building over the last decade, has now come to a head due to increased personnel costs and the costs of expanding and re-equipping the capabilities of the ADF [i]

Less the issues of funding, the impact the Internet economy on business is not dissimilar from the circumstances in defense. Businesses have had to cope with change or see their future jeopardized. The requirements for and the tempo of change in are intense.

In their study of Internet business, **Net Ready, Strategies for Success in the E-conomy,** Hartman and Sifonis map the change from the Traditional economy to the E-conomy, (Figure 1). The E-conomy being "the virtual arena in which business actually is conducted, value created and exchanged, transactions occur, and one-to-one relationships mature." [ii]

[i] Dr. Allen Hawke, Secretary of the Department of Defence, Australia from a paper based on an Address to the Royal United Services Institute for Defence Studies, Victoria, Australia, 27 April 2000.

[ii] Amir Hartman and John Sifonis, *Net Ready, Strategies for success in the E-conomy* (New York: McGraw-Hill, 1999) xviii.

Traditional Economy	E-conomy
Stable, predictable Franchise	Free-for-all
Economies of Scale	One-to-one relationships
Stasis; reliance on geography, capital	Movement
Positioning	Value migration
Long-range planning	Real-time execution (Agility)
Protect products, markets and channels	Cannibalize products, markets and channels
Predict future	Shape or adapt to future
Encourage repetition	Encourage experimentation
Detailed Action plans	Managing options
Structured formal alliances	Web of informal alliances
Aversion to failure	Failure is expected
Weak links between reward and outcomes	Direct links between risk and reward

Figure 1. The Change from the Traditional economy to the E-conomy [iii]

The current leading corporations of the E-conomy have not just changed but have done so in Internet time. (Operational cycles measured in Internet years where three months equates to a normal business year.) Also, they have established change as the organizational norm.

These changes in business and their impacts are relevant to the defense community.

A projection by the Giga Information Group states, "In 2002, the almost $1 trillion in predicted global Internet commerce revenues, will also generate cost savings of nearly $1.25 trillion, producing even greater profit margins than revenue growth, dollar for dollar. [iv] The take away point is that using Internet technologies will reduce or eliminate many costs by improving core business processes. This means the Internet is more than just a new way to sell products and services, it's a way to efficiently run a business, resulting in significant cost savings that add to an organization's bottom line.

[iii] Ibid. 6

[iv] Extract of Cisco Systems, Inc., Corporate Overview quoting from the Giga Information Group, Cambridge MA, 1999.

If only for the bottom line benefits of networked business process, Defense should leverage the business process changes of Internet commerce. Given the funding shortfalls in defense, it is hard to argue against implementing changes that are estimated to generate $1.25 trillion in savings. Put in historical terms, Cisco's Global Network Business Model has produced measurable savings of $325 million in 1997, $525 million in 1998 and $825 million in 1999.

Defense's businesses also have the challenge of adopting practices that are compatible with their major business partners. Besides the traditional defense contractors that are increasingly vested in commercial business as a source of growth, the deployment of commercial-off-the-shelf technology places defense squarely in the larger market place of business-to-business commerce. In this market the influence of defense's "power of the purse" is greatly reduced. It is an arguable point that the failure of defense to adopt commercial business practices may cause businesses to ask the question, "Is it better to forgo defense business than to deal with defense on a by-exception basis from the rest of my business partners?"

Even in major weapons system acquisitions the business-defense relationship has moved from favored customer towards that of consumer. The US Navy's acquisition of DD 21, the next generation surface combatant, is a competition between two consortia that have been challenged to design, build, and maintain the ship for its service life while making a profit. The Navy should expect, better yet demand, that the business system built around this ship is also state-of-the-art in business process. In selecting the winner the US Navy must fill the role of well-informed consumer. The Acquisition Warrior war games for DD 21 indicate the Navy has recognized the need for change in acquisition.

As the defense business broadens to commercial corporations and as the defense industrial base becomes increasingly a community of commercial-defense hybrids, then defense business process must move to the internet-based business-to-business model. The failure of the defense to adopt these practices will result in defense's marginalization from the mainstream business community.

The operational challenges are similar. Military forces must execute with a speed of command and technology level "better" than their adversary or accept the risk of "defeat" by an adversary who seizes the initiative by creating an asymmetric advantage through network centric operations or a leap-ahead technology.

The requirement for operational and technological change is collectively known as the Revolution in Military Affairs (RMA) — the drive to harness technology to ultimately bring about fundamental conceptual and organizational change in defense.

The RMA is characterized by leap-ahead advances in information technologies; by having no definitive linear process; and by its requirement for experimentation both to understand the potential contributions of emerging technologies and to develop innovative operational concepts to harness these new technologies. [v]

In the United States' Joint Vision 2010 (JV2010) information superiority is the capstone requirement for fueling achievement of the operation concepts of Dominant Maneuver, Precision Engagement, Focused Logistics and Force Protection. [vi]

Another term frequently encountered in this lexicon of operational change is Network Centric Warfare (NCW). Network Centric Warfare is defined as:]

> An information superiority-enabled concept of operations that generates increased combat power by networking sensors, decision makers, and shooters to achieve shared awareness, increased speed of command, higher tempo of operations, greater lethality, increased survivability, and a degree of self-synchronization. In essence, NCW translates information superiority into combat power by effectively linking knowledgeable entities in the battlespace." [vii]

Vice Admiral Cebrowski, President, US Naval War College comments,

> "Network Centric Warfare is increasingly seen as the military expression of the information age. More specifically, Network Centric Warfare enables promising alternative concepts of Command, Command relations, and Command and Control processes. [viii]

[v] William S Cohen, U. S. Secretary of Defense, *Annual Report to the President and the Congress* 1998, Washington, DC, 117.

[vi] Chairman of the U. S. Joint Chiefs of Staff, *Joint Vision 2010,* Washington, DC, 1.

[vii] David S. Alberts, et al, *Network Centric Warfare, Developing and leveraging Information Superiority,* C4ISR Coop. Research Program, Wash., DC, 2.
[viii] VAdm. Arthur K Cebrowski, USN, President, US Naval War College in his Convocation Address for Academic Year 1998, Newport RI, Aug 1998.

In the chapter "Information Age Organizations" in **Network Centric Warfare, Developing and Leveraging Information Superiority,** the authors note that commercial "organizations that have been able to fully leverage the power of information and information technology (IT) to develop competitive advantage have dominated their competitive domains." They also make note "that business is not warfare ... But to dismiss a potentially rich source of hypotheses . . . is as foolish as it is unnecessary." In this recognition of the changes in the networking industry, they make the point that defense is between 1- and 10-percent plus of the $600 billion-plus Information Technology market. Also, it is this sector where the case studies and insights are available to help defense become an information age organization. [ix]

<u>The Operational Art -- Change requires leadership and vision. It also happens over time.</u>

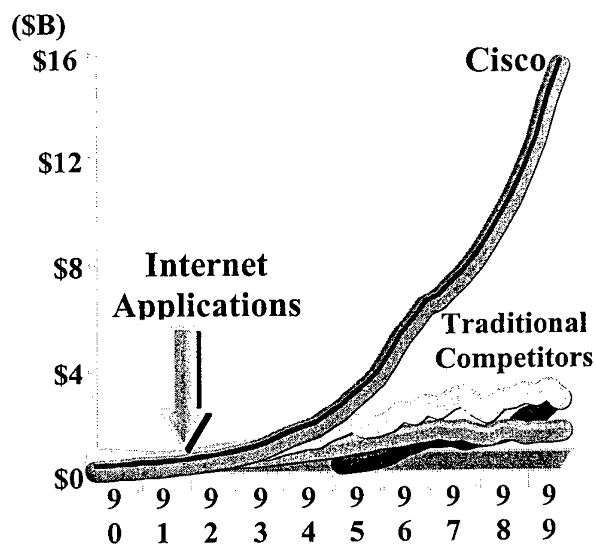
The operational level is the link between tactical success in combat and what ultimately in war is success -- attaining the aims of policy. The operational art is the ability to envision the actions required to achieve the strategic end state by using the available forces, time, space and resources to create advantageous position from which to enter a series of meaningful battles. This series is a campaign and it is the primary tool of operational warfare. [x]

In his discussions of Network Centric Warfare VAdm. Cebrowski states " Furthermore, there is the fundamental question of what the commander commands -- forces, information services, or key processes?" [xi]

Likewise in business, the question of what a "commander commands" is critical to the changing nature of business and the business leader's success in orchestrating change. It is a question answered by Cisco in developing its Global Networked Business Model and subsequently more formally in **Net Ready - Strategies for Success in the E-conomy**. As defined in **Net Ready**, Net Readiness® is "a combination - unique to each Company -- of four drivers that enables enterprises to deploy high-impact Web-enabled business processes that are focused, accountable and measurable." The drivers are leadership, governance, competencies and technologies.

In the Net Ready businesses, the question, 'Who commands what?" is addressed by the leadership and governance pillars. While "available forces, time, space and resources" may be equated to the competencies and technology pillars.

The fact that the end state of Net Readiness is to develop processes that are focused, accountable and measured again make studying Cisco's change from a traditional manufacturing company to a network centric corporation a case study of interest T&E community. I've mentioned the savings realized from 1997 to 1999 by Cisco's network centric business model. Figure 2 depicts Cisco's Breakaway performance against its Traditional Networking Industry Competition since commencing its campaign of Internet business. It's a testimony of success through the adoption of a network centric business model where information availability creates value add.



Source: Bloomberg
Notes: Dates are calendar years, Numbers are annualized from most recent reports

Figure 2: Cisco's Breakaway performance against its Traditional Networking Industry Competition [xiii]

[ix} David S. Alberts, et al, *Network Centric Warfare, Developing and leveraging Information Superiority,* C4ISR Coop. Research Program, Wash., DC, 23 - 27.

[x] U.S. Marine Corps, Fleet Marine Force Manual 1-1, Quantico, VA.

[xi] VAdm. Arthur K Cebrowski, USN, President, US Naval War College in his Convocation Address for Academic Year 1998, Newport RI, Aug 1998

[xii] Amir Hartman and John Sifonis, *Net Ready, Strategies for success in the E-conomy* (New York: McGraw-Hill, 1999) 3.

[xiii] Extract of Cisco Systems, Inc., Corporate Overview quoting Bloomberg, Mar 00 version.

The Four Pillars of Netreadiness® - Leadership, Governance, Competencies and Technologies.

In their study of E-conomy successes, Hartman and Sifonis studied 400 companies and culled the success traits in companies as Cisco Systems, Microsoft, Charles Schwab, Dell Computers, eBay, and Amazon.com. They found that there are in an infinite variety of permutations of leadership, governance, competencies and technologies that are consistently displayed by the most successful companies. [xiv]

Originally examined with a singular vision in a Cisco White Paper "Global Networked Business Approach and Architecture [xv]," the in-depth analysis of **Net Readiness** broadens the horizon of source data and gives greater academic credence to defining the requirements for success in the E-conomy. In this paper I can only give a brief description of the pillars. I hope however it encourages further study of the drivers for implementing network centric change.

Leadership. Most of the success stories in the E-conomy have a recognized leader at the helm but the leadership pillar is more than the persona of a key individual. Leadership is a pervasive quality of successful network-centric businesses. Every member of the organization must be a leader. From the CEO on down, each team member must think and act in E-conomy terms, use E-business tools, and be accountable in clearly measurable ways for pursuing the network centric end-state. The overarching leadership message is that network centric culture runs from top to bottom, and everyone is empowered to support and propagate business focused on that culture. "The leader's job is to promote this vision by personal example." [xvi] As they did at the macro-level of the old and new economies, Hartman and Sifonis have mapped the Qualities of Net Ready leadership of the Traditional CEO and the Net Ready CEO, Figure 3.

[xiv] Amir Hartman and John Sifonis, *Net Ready, Strategies for success in the E-conomy* (New York: McGraw-Hill, 1999) 3 - 4.

[xv] Cisco Systems, Inc., *Building a Global Networked Business,* San Jose CA, 1998.

[xvi] Amir Hartman and John Sifonis, *Net Ready, Strategies for success in the E-conomy* (New York: McGraw-Hill, 1999) 5.

Traditional CEO	Net Ready CEO
"Do as I say"	"Do as I do"
"Get out of my way"	"Get on my team"
Focused on strategy	Focused on execution
Constrained by money	Constrained by time
Encouraging	Evangelizing
Cautious	Paranoid
Gets to "yes"	Is able to say "no"
Concerned with the long term	Concerned with the short run
Has a preference for comfort	Insists on truth
Market driven	Customer driven
Intolerant of ambiguity	Welcomes ambiguity
Sequential	Multitasking
Focused on retention	Focused on recruitment

Figure 3: Qualities of Net Ready leadership of the Traditional CEO and the Net Ready CEO [xvii]

As you read this list I've little doubt you found yourself questioning the applicability of some of traits to defense executives. This is yet another challenge for the defense community in this time of change. Its leaders and managers must have the intellectual flexibility to cull from the wide variety of findings about business process change the points that are useful even when the explanations and examples have nothing to do with defense. Defense leaders must be able to envision the actions required to achieve the strategic end-state. They must practice the operational art. Defense leaders know "that business is not warfare" as well as the fact that defense business is not commercial business. The point made about Network Centric warfare earlier remains, not " . . . to dismiss a potentially rich source of hypotheses," because it is not a one-to-one mapping.

Governance. This determines the nature of the relationships within and outside the formal organization. Think of the US Department of Defense as you read the following.

> "A modern enterprise consists of multiple business units and, in many instances, overlapping business functions, administrative, manufacturing, marketing, support and so on. To successfully drive E-

[xvii] Ibid. 6.

[xviii] David S. Alberts, et al, *Network Centric Warfare, Developing and leveraging Information Superiority,* C4ISR Coop. Research Program, Wash., DC, 24.

business, an organization must have a mechanism that enables it to cross all these functions, taking responsibility for business initiatives spanning different operating units." [xix]

Successful network centric corporations have defined their governance and operational frameworks to handle continuous and rapid change by focusing on four core disciplines: the governance model, the decision process, the policies and standards for implementing change, and the goals and metrics defining performance objectives and their measurement.

Governance lessons that standout from the studies of Hartman and Sifonis include:

- Establish cross-functional teams.
- Demand near-term E-business results.
- Actively promote the use of E-business applications.
- Make E-business a business-driven activity, not a technology-driven staff function.
- Make E-business funding decisions resemble all business funding decisions.
- Establish a cross-functional governance council with-business, technology and evangelical components
- Make IT take on a free market fulfillment role.

[xx]

Technology. This is not technology in the narrow sense of protocols and individual standard but technology from an operational perspective. The successful Net Ready companies have developed architectures that are robust and comprehensive, that enable them to develop and deploy new applications without the having to rework the infrastructure - the network, data security and databases, with each change in the way they do business in a segment of their business.

[xix] Amir Hartman and John Sifonis, *Net Ready, Strategies for success in the E-economy* (New York: McGraw-Hill, 1999) 13.

[xx] Ibid. 18.

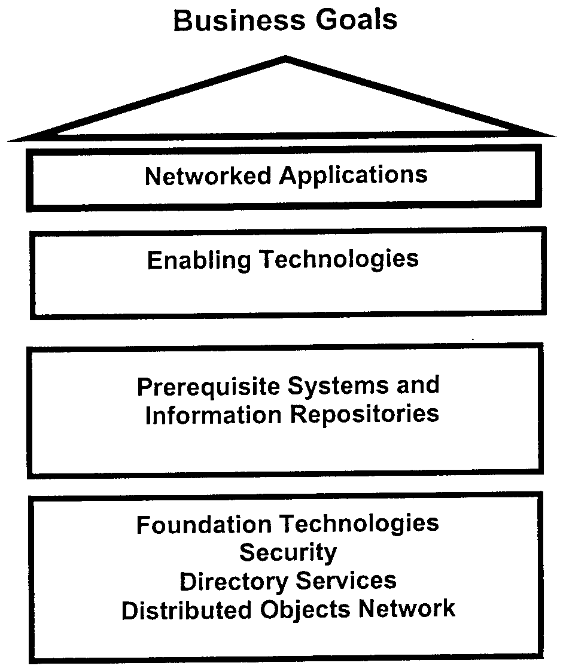


Figure 4: Technical Architecture

Competencies. Just as information superiority is an enabler for the operational concepts of Joint Vision 2010, competencies are the cement of governance, leadership and technologies for Net Readiness®. Competencies are defined as "the ability to navigate among the these values.... Competencies determine the way Net Ready organizations respond to changes in the world, exploit available resources and opportunities and accommodate themselves to emerging realties." [xxi]

Now, with this framework let's briefly examine Cisco Systems.

Cisco's Network Centric Campaign

Since 1992 Cisco has been a company in change. These changes were business critical changes to meet the challenges of scale, the speed of technical innovation of the networking industry, the need to stream line business process, and the need for communications with customers, supplier, partners and employees.

Corporate business discussions use the same terms as the military -- "vision", "strategy", "tactics", and "risk management."

[xxi] Ibid. 19

At Cisco the strategic end-state is hardly a modest one. The corporate vision is "Changing the way we work, live, play and learn." The mission derived from this is "Shape the future of the Internet by creating unprecedented value and opportunity for our customers, employees, investors and ecosystem partners." The Cisco Global Networked Business Model highlights Cisco's ability to connect strategy to tactics -- the operational level. As for the art of campaign, Cisco's ability to sustain a continuum of change to create business advantage is best demonstrated by both the savings and breakaway performance mentioned above.

The discussions in **Network Centric Warfare** highlight the requirement for the co-evolution of organizations and process while exploiting new technology. More importantly it notes that organizations have different time constraints with respect to change. [xxii]

In "Net Readiness at Cisco Systems" Cisco's co-evolution has been characterized as follows:

> "We believe the Cisco story reveals the impact that a sustained dedication to the principles of Net Readiness® can bring to an organization willing to accept its disciplines. But Cisco's success was not inevitable. It would be a mistake to assume that the seamless electronic processes that enable Cisco emerged out of a well-ordered, analytical process. What really happened is that a lot of dedicated Cisco people responded to a clarity of vision with a large number of initiatives, many of which proved to be quite effective. More important, Cisco's evolvement didn't happen overnight. In fact, the Cisco story is the product of five years of effort, millions of dollars in investment, and hundreds of projects, not all of which proved sustainable." [xxiii]

The methodology for Cisco has been a series of tactical changes and experiments within a visionary framework centered on customer service and creating value-add for all Cisco's partners.

[xxii] David S. Alberts, et al, *Network Centric Warfare, Developing and leveraging Information Superiority,* C4ISR Coop. Research Program, Wash., DC, 2 & 4.

[xxiii} Amir Hartman and John Sifonis, *Net Ready, Strategies for success in the E-conomy* (New York: McGraw-Hill, 1999) 239.

Of particular note at Cisco is the demand by and tolerance of Cisco's leadership that risk taking is the expected course of action. Cisco is not a not-born-on-the-web company but it is a company that recognized very early the strategic, operational and tactical implications of its market and business environment. Change at Cisco isn't a function of a "big bang" that attempted to resolve all the issues. It is a series of steps that encourages risk, rewards success, and creates a community that accepts that not all projects are successful.

As mentioned previously, Cisco's challenges in the early 90s were the drivers for its network centric business model. At that point Cisco needed to find a way to scale its operations in the face of explosive growth in the networking industry. It could not rely on finding enough skilled engineers to build and service its products and its customer's questions. Customer satisfaction levels, though respectable, were stagnant. As customer satisfaction is its major metric of success, the company had to find a way to raise the satisfaction levels of its expanding customer base. Additionally, for continued growth it needed to focus on it's core competence - product design and innovation, not on fielding a team to answer questions and provide "build to order" products for customers. Consequently Cisco also decided to outsource manufacturing to a select group of partners. The challenge here was ensure consistently high product quality across its supplier base.

The chosen course of action was to use "Internet Business Solutions" - leveraging the Internet and networked applications to allow customers and employees access to self-service tools, and to automate repetitive manual activities. Cisco's first step was an electronic bulletin board for customers. It was introduced in 1992 to post tech notes, provide software upgrades and reveal information on its software bugs. Shortly after Mosaic was introduced, Cisco allowed registered users with a support contract access to limited online support features. You've seen the overall Breakaway performance chart (Figure 2). Figure 5 shows Customer Satisfaction on a 5.0 scale over the same period.

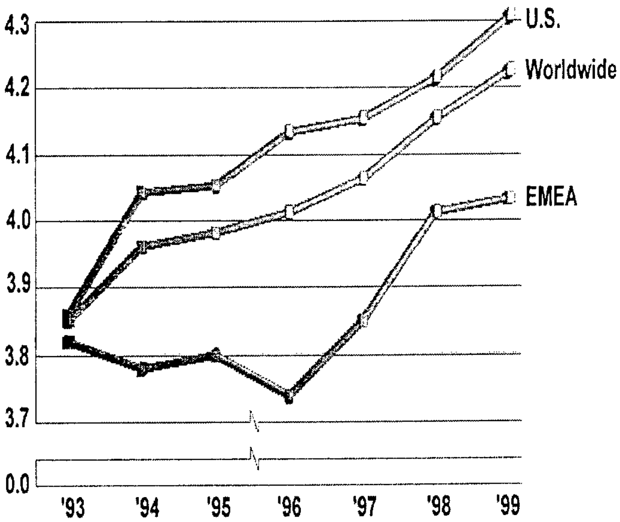


Figure 5 Customer Satisfaction [xxiv]

As seen in Figure 4, Technical Architecture, the technologies pillar allows for deployment of prerequisite systems, enabling technologies and networked applications. Figure 6 is a table of the Capabilities Architecture for Cisco's Technical Information Center, and the series of figures at the end of the paper show how Cisco built the capability into its Internet-based solutions over time. In this case the Cisco Connection Online (CCO), our link to our customers.

	Enabling Technology	Prerequisite System	Networked Applications
94	Adaptive Content Document Management	Customer/ Contract Info Prod. Info. Defect Tracking	Bug Navigator Tech Tips Product Data Center
95	Knowledge Tools Collaboration	Technical Tips Collection & Manage-ment Call Tracking	Trouble Ticket Case Query Open Forum
98	Electronic Distribution Work management	Service Order & Maintenance	Trouble-Shooting Engine Proactive Field Notes Stack Decoder

Figure 6: The Capabilities Architecture for Cisco's Technical Information Center

[xxiv] Extract of Cisco Systems, Inc., Corporate Overview quoting Bloomberg, Mar 00 version.

Beyond the revenue and customer satisfaction measurements, the "box score" for Cisco's online customer care solutions is

- 70% of support calls are resolved by a visit to our website.
- $86M saved with electronic downloads,
- $107M saved with online configuration and documentation,
- $40M in products sold online each day, and
- 87% of orders placed online.

Similar results can be found in the Cisco Manufacturing Online solution for working with our partners in the supply chain, logistics and contract manufacturing area, and our employees through the Cisco Employee Connection. The Manufacturing box score is

- 70% cut in order cycle time (6-8 weeks to 1-3 weeks)
- $175M savings in annual operating costs
- 45% inventory reduction for Cisco and partners
- Time-to-volume cut by 25%; $270M annual revenue contribution

While the Cisco Employee Connection is as impressive with

- Self-service administration and information resources for 20,000 employees,
- Two auditors and 2-day reimbursement for 16,000 U.S. employees,
- Purchasing, recruiting, stock options and nearly all employee services handled via the intranet,
- 40-60% cost savings vs. instructor-led training,
- 80% of sales and technical training on line,
- 100% of Cisco sales staff to use e-learning for training in FY 2000, and
- E-learning available anytime, with anywhere access and full training accountability.

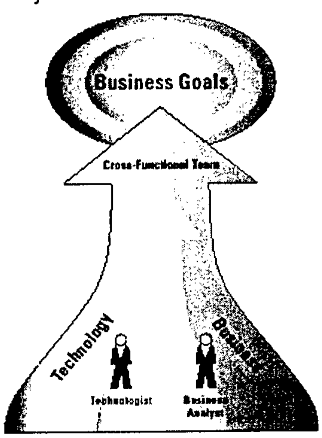
As stated previously the impact of Cisco's Internet solutions for 1999 were $825,000,000. Figure 7 shows the bottom line results of the changes -- The Financial Benefit by Internet Business Solution.

	Financial Benefit
Customer Care	$269,000,000
Internet Commerce	$57,000,000
Supply Chain Management - Cost benefits - Profit contribution	$444,000,000 $175,000,000 $269,000,000
Workforce Optimization	$55,000,000
Total Financial Impact	$825,000,000

Figure 7. Financial Impact

Of the many points to be drawn from Cisco's success in the E-conomy, Cisco's governance model must be considered as one of the significant contributors.

Information Technology (IT) funding is based on a free-market fulfillment model called the Client Funded Project model. The model is focused on a



teaming approach between the business units and the IT department Figure 8.

Figure 8. The Business - IT team [xxv]

The management philosophy is built around four major ideas:

- Cisco's business units drive the applications to be deployed.
- Business units within Cisco consider the cost of deploying applications as a cost of doing business. The costs are assigned to the business unit that gains the advantage and only when benefit cannot be directly attributed is the cost treated as corporate general and administrative expense.
- Business and IT teams implement applications together and their performance is based on a team evaluation.
- The Chief Information Officer strictly enforces standards. This avoids the cost of duplicate or unnecessary spending created if a business unit were to deploy their own unique technology or a standard that is incompatible with the rest of Cisco. [xxvi]

[xxv] *Global Network Business Approach and Architecture White Paper,* (San Jose, CA: Cisco Systems, 1998). 8.v

Incompatibility is unacceptable. An imperative of the networked business is that no one owns information, they have the responsibility to maintain its currency so the best and latest information is available to whoever needs the information to conduct Cisco's business.

Summary. In the discussions of "Shaping T&E to Support the Evolution of Future Defence: Changing military, government and industry roles to meet new challenges" Cisco's story offers many lessons. They run the gamut from the strategy, operations and tactics for implementing change over time, through the dynamics of the change process, to providing examples of what are the business processes of network centric operations.

Although not one hundred percent applicable, Cisco's successful series of changes during the 1990's is an experienced-based insight into changing. To again quote the authors of Network Centric Warfare " But to dismiss a potentially rich source of hypotheses . . . is as foolish as it is unnecessary" [xxvii]

The frustration is that there are too few pages to give more than a sampling of the material and the selection of the samples, even for a community of interest such as the Test and Evaluation Community, is at best a process of trial and error.

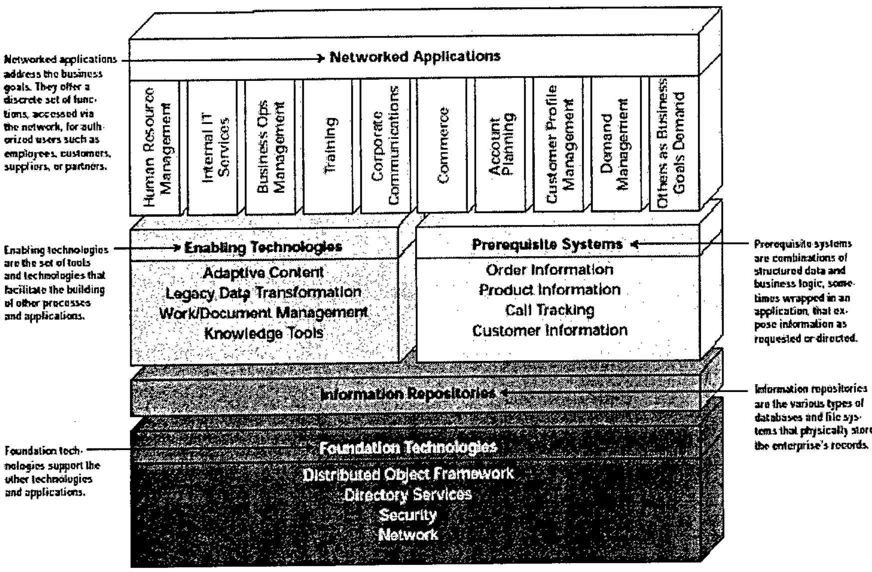
One of the first things a new Cisco employee hears from his counterparts as he or she starts to explore the company's products, set-up their benefits, or arrange for a corporate credit card is "its on the web!" I'll end with that idea, much of what's in this paper about Cisco is on the web at www.cisco.com.

[xxvi} Amir Hartman and John Sifonis, *Net Ready, Strategies for success in the E-conomy* (New York: McGraw-Hill, 1999) 239.

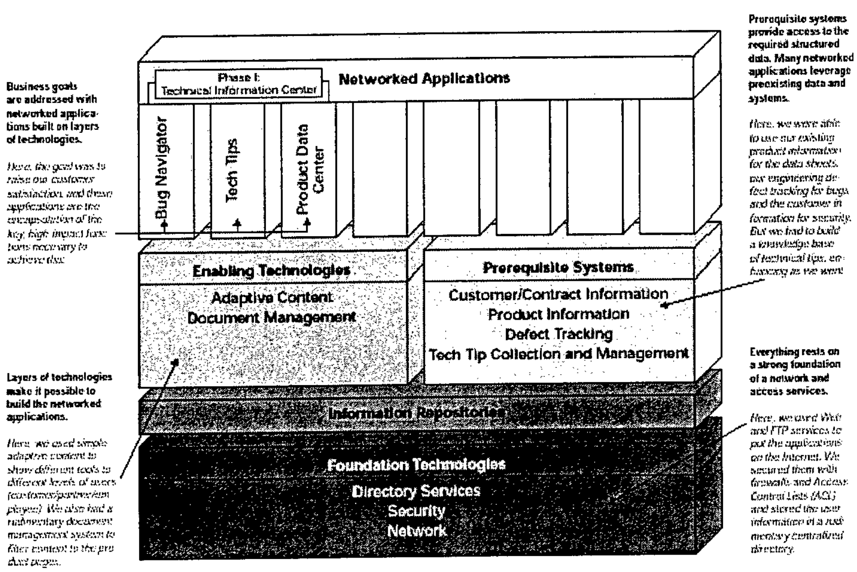
[xxvii] David S. Alberts, et al, *Network Centric Warfare, Developing and leveraging Information Superiority,* C4ISR Coop. Research Program, Wash., DC, 2 & 4.

The Global Networked Business Architecture and build-out of the Cisco's Technical Information Center

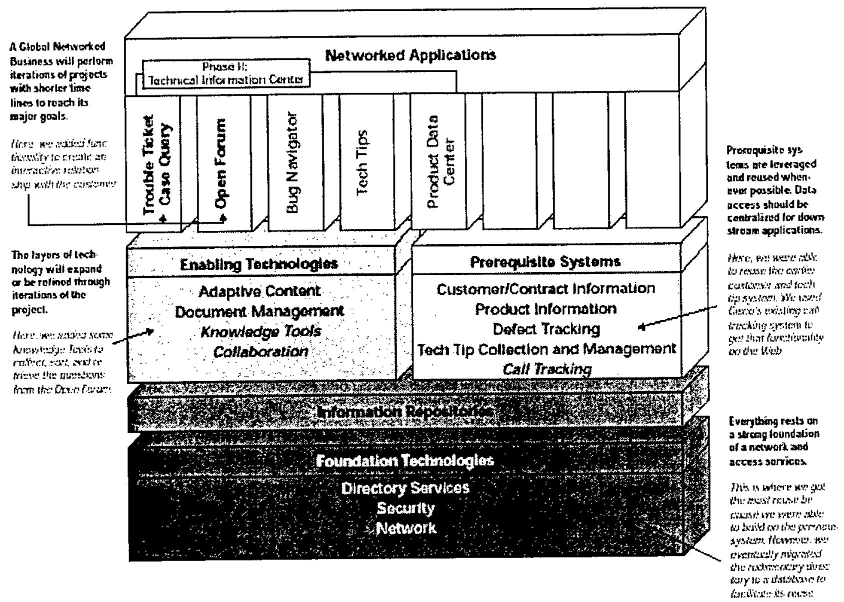
The Cisco Global Network Architecture



Cisco's Technical information Center Phase I, July 1994

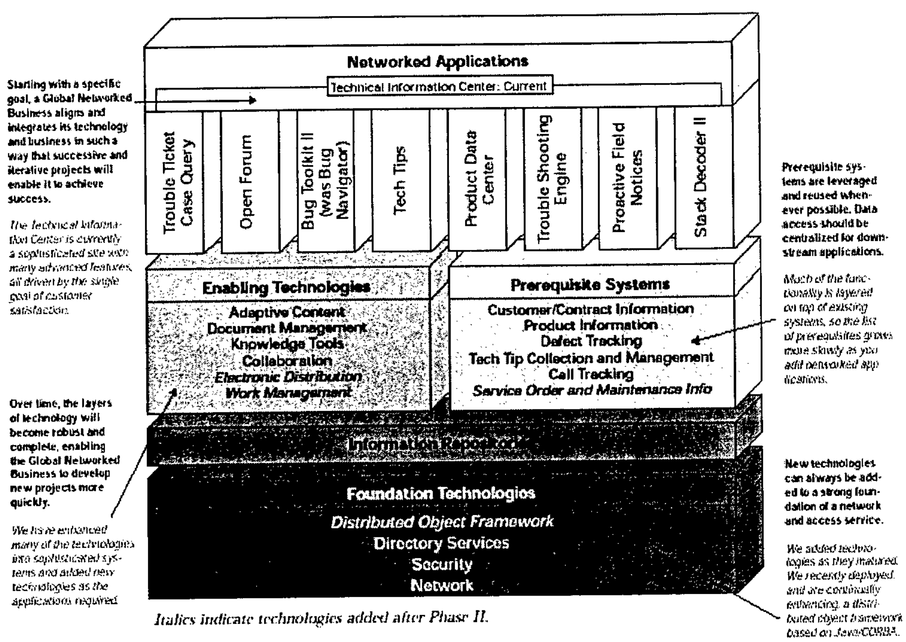


Cisco's Technical information Center Phase II, April 1996



Italics indicate technologies added in this phase.

Cisco's Technical information Center Phase III, March 1998



Italics indicate technologies added after Phase II.

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Jaguar New Model Launch Processes

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JAGUAR NEW MODEL LAUNCH PROCESSES

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Abstract

The introduction of the XJ 40 series of Cars in the mid-eighties saw a low point in Jaguars product launch performance, with the wrong product, poorly defined, late and with disastrous Quality and Reliability. There followed several years of updates, which attempted to bring the car up to the level of the competition. This action may have been successful in different economic circumstances, but in a recession it led to massive losses and the eventual take over by Ford.

After the take-over major improvements were made to product quality, working practices and manufacturing capability. The production sites at Browns Lane and Castle Bromwich gained the Ford Q1 Quality award and investments were made in new production facilities. The next step was to update the product; based on past performance this would be a major risk.

The product was to be a major facelift to the saloon range; a successful launch was internally regarded as a survival issue as failure would surly mean that Ford would withdraw its financial support. It was with the scenario that failure would lead to Jaguar ceasing to exist as a pseudo independent entity the launch was planned.

The best way forward was deemed to be to adopt a whole new launch philosophy, which encompassed the best practices from within Ford. This was done while maintaining the leverage gained from a relatively small company which can retain a nimbleness of process and drive out the functional chimneys that often dominate larger organisations.

This Launch Process was successfully deployed on the 95 Model Year XJ series, codenamed X300, which proved to be the most successful Jaguar Launch to that date. Subsequent refinements have been made and it is the process, which is a result of those refinements, which is in use today and will be the main topic of the discussions that follow.

Jaguar New Model Launch Processes

Introduction

With the successful introduction of the Jaguar S-Type and the planned launch of the X400, the company finds itself in a much-changed environment from that which greeted the X300 launch in 1994.

Product quality is no longer a source of competitive advantage. It is a prerequisite for sustaining a position in the market. The introduction of advanced quality tools and techniques were therefore critical to the success, of the programme.

In 1994, we were seen as a quaint British Marque producing low volume interesting and stylish cars that deserved praise for its efforts but was not really a serious competitor to either BMW or Mercedes Benz. This gave us the enviable position of having a very forgiving World Press and competitors who were too preoccupied with each other to be concerned with Jaguar. With annual volumes planned to rise above 200,000 units, we are now seen as a serious car company and treated as such with much more critical appraisals and competitor activity.

The next new Jaguar Car must demonstrate the highest standards of excellence in British Engineering and represent a further significant advance for Jaguar, building on the foundation established for the XJ6 saloon car project launched in the mid-nineties and re-enforced in subsequent Product Launches.

Jaguar's engineering expertise, working in close collaboration with its suppliers, has enabled world class-leading products to be launched, which demonstrate all the attributes of 'Manufacturing Excellence'.

The Company's competitive performance in world-wide markets is expected to be much enhanced by the launch of future products such as the X400 with significant improvements in quality and process efficiency throughout manufacturing operations. Customer satisfaction levels are planned to surpass leading German and Japanese competitors.

This submission on behalf of Jaguar Cars Limited identifies the Launch Team Structure and working ethic together with 8 key elements, which constitute the Launch Processes. The combination of these has contributed to the quality of new model launches, although the Cultural Changes within Jaguar have been without doubt the single biggest factor.

The Launch Team

Approximately 16 months from Job 1 a Launch Team is formed, this comprises in the order of 200 full time Product, Manufacturing and Production Engineers, Purchase agents, Finance Analysts and On-site Supplier Representatives. The team is collocated at the production site and effectively eliminates departmental barriers, and creates the sense of urgency necessary for rapid change. They as a team have responsibility for ensuring the project goes into production on time, on budget and most importantly achieving the required quality objectives.

Structure and Managers

The structure of the Launch Team has in three legs, where activities of a similar nature are grouped together. The car itself is broken it to two areas, Body and Trim being controlled by one manager and Powertrain, Chassis and Electrical by a second. The third manager of the team will control the Manufacturing Process and Facilities. These managers are selected such that their characteristics and strengths are a good match for those required to fulfil the role. This selection is critical to the overall success of the process; its importance is often overlooked, as there is often pressure to take the three best managers from the organisation when the project is of a critical nature.

With the Body and Trim the main focus is on cosmetic appearance and dimensional stability. The body panels must be dimensionally correct and their surface finish is critical to the showroom appearance of the car. The aim is to create the impression that the car is hewn from a single block of material and not a collection of elements loosely hung together in a haphazard way. This illusion is enhanced if the gaps and margins are as small as possible and above all uniform. The interior is treated in a similar way in an attempt to create the illusion of a single entity from a form perspective while the various materials are used to create soft feel zones and create a luxurious atmosphere.

In this role it is attention to detail and a continuous drive towards cosmetic perfection that is required. The problems are not often complex but the solutions are difficult to achieve, but the manager is required to be ruthless in driving the team forward as success is directly proportional to effort

The Powertrain, Chassis and Electrical managers' role presents a very different set of problems as rather than cosmetic appearance being important it is the function that is complex and often at issue. The solutions are complex in nature and undesirable system-to-system interactions are not uncommon, but can be difficult to isolate even before the task of establishing root cause and fixing the problem begins.

Here the role is more one of coaching people through the problem resolution process step by step without getting frustrated. In this area there are few quick fixes. A structured approach to establishing root cause and verification is paramount. Failure to do so will result in partial containment and re-emerge at a later date as an issue with the customer.

The third manager controls the build process and the installation and commissioning of any new facilities. The size of this role depends as much on the state of the current production facilities as it does the size of the product change. In the case of X400, where we are installing a new paint plant, new body construction facility and a new trim and final assembly line, the skills required is of a project management nature dealing with large international companies who are installing the new production facilities. These contracts total over 400 million dollars and thus the day to day activity is controlled by the major contractor in each case and the role of the Jaguar Launch Manager is to oversee the individual projects ensuring they are integrated and deliver a total production system on time.

Operating Practices

Some practices that it would be difficult to describe as processes but never the less are rigidly adhered to and provide the foundation upon which many of the launch processes are built. These are outlined below in limited detail to set the overall scene and aid the understanding of the main launch processes.

During the launch there will be a daily start up meeting, representation from all the functional areas is mandatory and it is normally attended by the leaders from each team. Here all immediate issues are discussed and a consensus as to the way forward is agreed this is then communicated to the rest of the team and there is no confusion. Progress on vehicle build and major facilities would be reported together with an outline of planned activities of the day where they may affect other areas. The various program metrics would be displayed at this meeting, but would only be discussed if there were a significant update.

All issues or problems relating to the program are tracked through AIMS (Automated Issues Management System), which is a comprehensive database that has various automatic dating routines, allows teams to be assigned to individual problems and is available through the internal network at all the Jaguar Sites. All new AIMS are presented at the start up meeting and a champion is assigned, it is then tracked as part of the Champions AIMS open list to closure. The team assigned will work towards a resolution ensuring all relevant data is recorded within the database, progress against each open AIMS is reviewed weekly with the Champion in an Exceptions Meeting.

The Launch Managers have weekly exceptions meetings with each of their designated launch champions where they review the severity and progress of every open AIMS assigned to that champion. These ensures progress is being made and if required the Launch Manager can give direction, assign more resources, free up road blocks or enlist the assistance of some external specialists.

If the resolution of an issue requires a change to the product, the change instruction is issued via WERS (World Engineering Release System); this constituted a formal engineering release, which will trigger an order from purchase. The financial function within the Launch Team advises on the cost affordability of the potential solutions within AIMS and will now formalise those costs. Where cost increase is involved, the launch philosophy is to protect the customer and quality levels, but to find ways to make the change affordable.

The change notice, with agreed costs and lead-times is now taken to the daily CMM (Change Management Meeting) where the change is formally agreed. This is chaired by the Launch Managers and has attendance from Purchase, PMC (Production Material Control), Manufacturing and Finance. The details of each change notice in terms of cost, lead-time, ability to resolve the issue and manufacturing feasibility are presented and if agreed the order will be placed the same day.

This relentless daily routine will handle over 12000 AIMS issues, 2000 engineering changes and co-ordinate the build of some 600 prototype vehicles. These are all monitored against key metrics which are reviewed weekly and their progress against previously agreed targets reported at the formal launch reviews.

Launch Process Elements

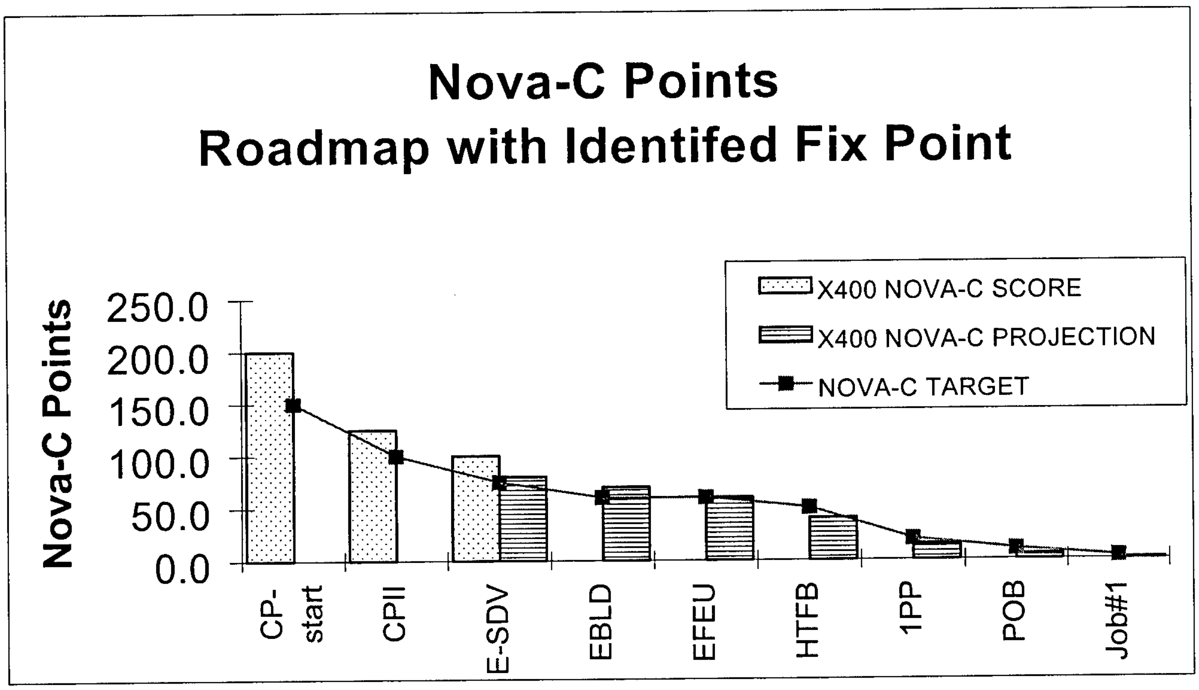
Launch Metrics

The program is assessed against internal measures or Launch Metrics which allow program-to-program comparisons and some of which can be carried forward into production to drive continual improvement initiatives. Metrics targets are established by benchmarking previous programs and best-in-class opposition and are set for each build phase and progress against these targets is reviewed at monthly Launch Reviews.

Functional Images:
The status is reviewed as evaluated by the Vehicle Office in areas such as Ride, Handling, Steering Feel, Noise Vibration and Harshness, Braking Performance etc. against the objectives which were set at program approval.

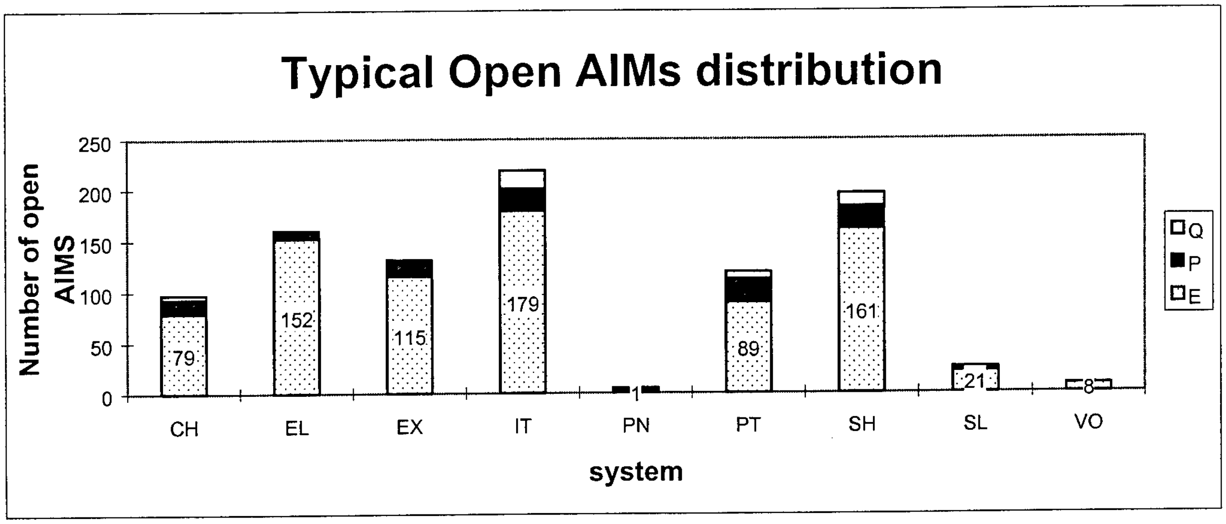
DVPSOR:
This is the Design Verification Plan and Sign Off Process, where by the Engineering test status for each system and the vehicle as a whole is reviewed against the predetermined sign off requirements.

NOVA-C:



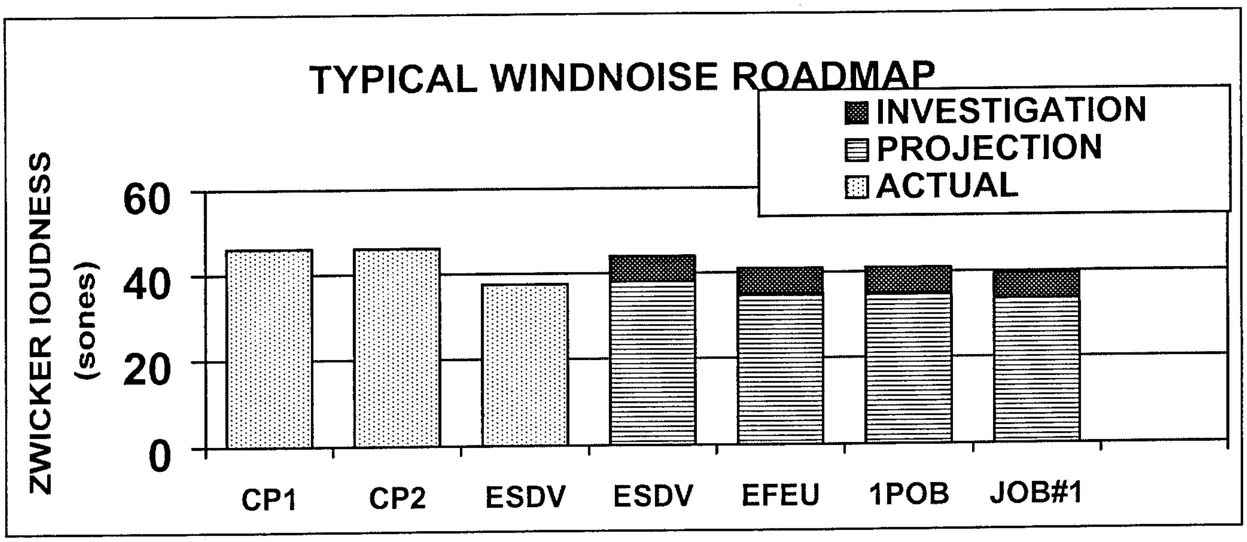
This is the normal plant quality audit process where faults are recorded and depending on the percentage of customers who would notice the issue a demerit score is assigned. These scores range from 9 points where greater than 90% of customers would notice to 0.1 where 1% of the Customers would notice a particular issue.

AIMS:



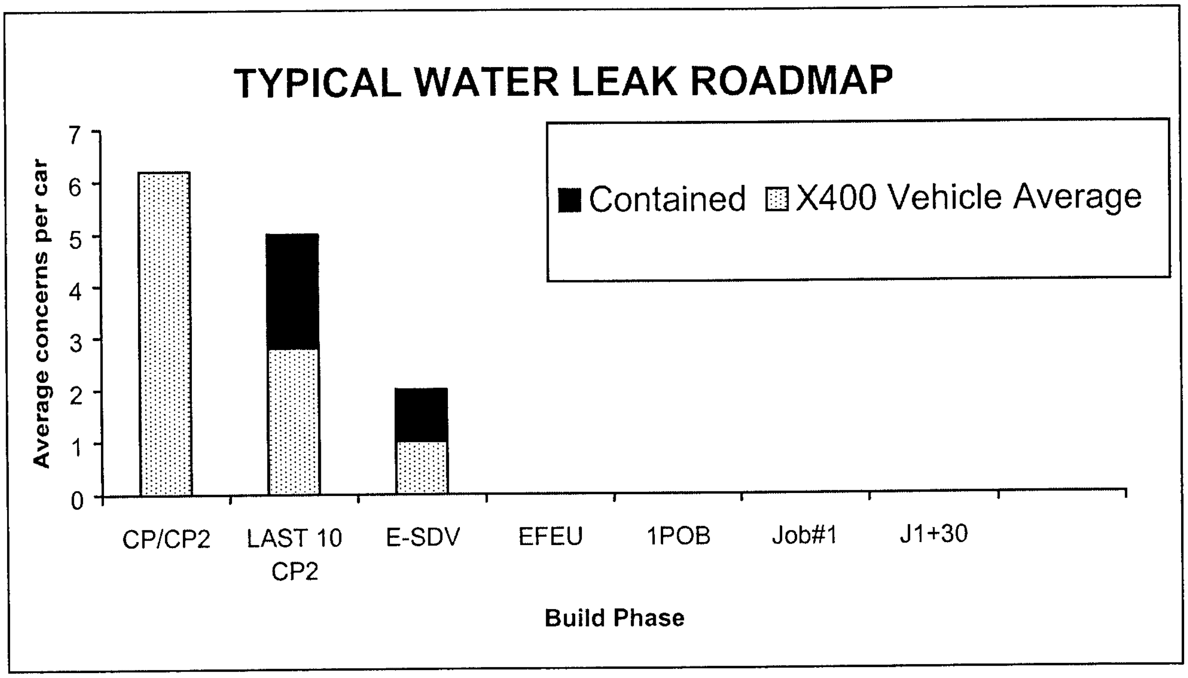
The number of open AIMS is tracked to give an overall view of the work outstanding for the Launch Team. The closure rate, severity and progress towards closure are also reviewed as this gives a much broader view of the health of the program. A high number of low severity AIMS with a high closure rate is obviously a more healthy state than a low number of high severity AIMS which cannot be resolved.

Windnoise:



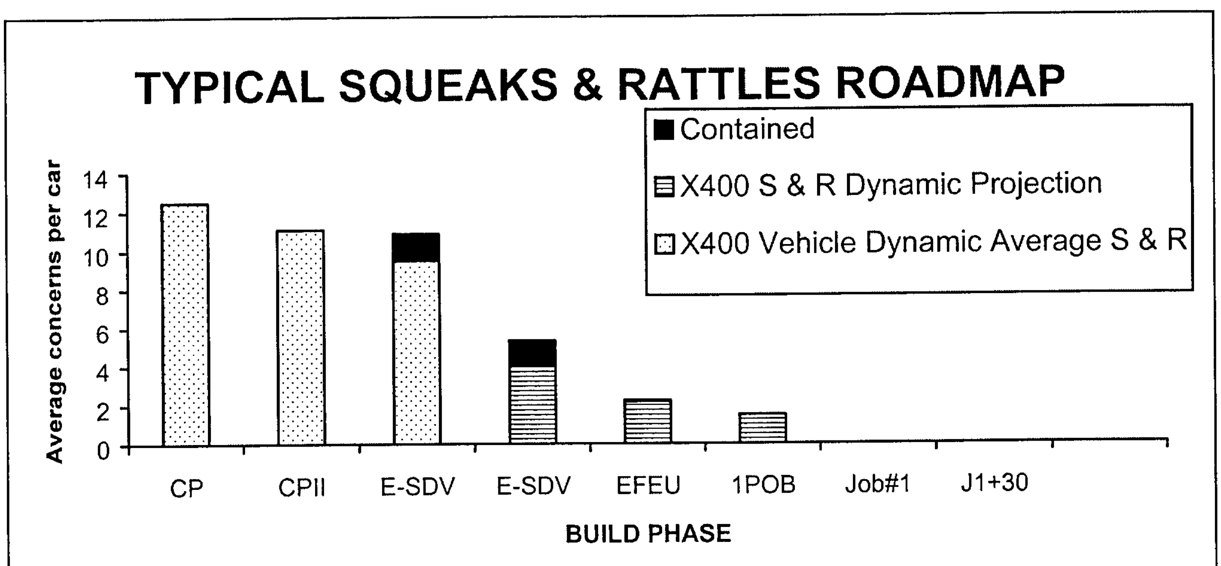
The windnoise of each vehicle is tested during the road test and given a standard rating on a scale of1 to 10. This is the normal ongoing production process, which is relatively good at detecting outright failures and trends as the average score is reported. To establish the absolute level of performance one car out of each build phase is taken to a high-speed wind tunnel to ensure repeatable conditions, this measurement in sones is then compared to the target, which was established by similar exercises on competitor products.

Water Leaks:



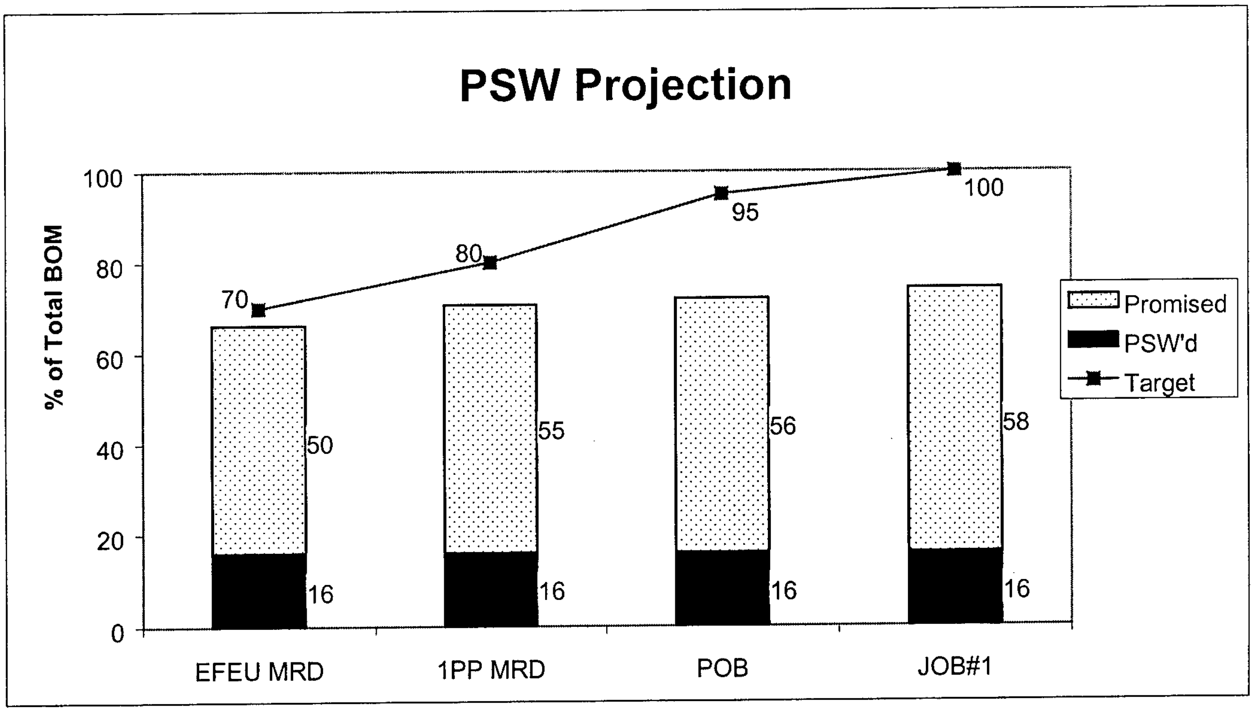
All vehicles are subject to a monsoon type water test using the standard production test facility; the number of water leaks per car is then tracked against the objective that was set at program approval.

Squeaks & Rattles:



This is assessed on a hydraulic shaker rig called a Hydropulse; the number of squeaks and rattles per car is then reported against Program Objectives. This has recently been expanded to include all static noises, tests at extremes of temperature and 50,000 mile rig simulations. These are reviewed at the launch review, but are reported separately, as there are no program objectives or historical data to use as a comparison.

Parts Status:



Each part is required to be signed off against its Functional, Dimensional and Cosmetic requirements. This is achieved via PSW (Part Sample Warrant), each supplier is required to submit a PSW promise date against the latest level parts. These promises are then plotted against the program timing to establish what percentage of parts will be approved at each build phase. This gives a measure of the risk to production, as vehicles with non-approved parts cannot be sold. Obviously the level of ongoing engineering change has a direct impact on PSW, as a modified part must be reassessed against the new criteria.

Manufacturing:
A manufacturing status against plan will be reviewed in the areas of Facilities, Process and Training giving an overall Manufacturing Risk Assessment.

Launch Reviews

These are held monthly and are chaired jointly by the Executive Director of Manufacturing and the Vehicle Line Director, its purpose is to establish the overall health of the launch which can the be communicated to other areas of the company not directly involved.

The agenda is set by the Launch Chief Engineer, but as a minimum it will include a review of each of the Launch Metrics against the current build phase target and the level of confidence of achieving the Program Targets at Job 1. Additional items would be included where a compromise was being proposed; the original targets had been changed due to external factors. The senior nature of the attendance also allows management guidance to aid resolution of key issues and concerns, having gained authority for a change in this forum it is rarely challenged which minimises the delays often caused by interdepartmental objectives.

Full Service Suppliers

Here in addition to the production of components, a supplier with relevant expertise in a particular area is given Design, Development and Release Responsibility. This type of action usually covers major car systems such as the electrical wiring System or Interior trim systems.

Quality deliverables are defined as an integral part of the design brief or target agreement. Competitive quality criteria defining the product in terms of the best practice are identified and the supplier is responsible for design, development and production of the component or system within the target agreement, in terms of quality and cost.

Suppliers' participation is planned from the concept stage of the design process. Suppliers are fully integrated, and in Simultaneous Engineering teams work closely with Jaguar personnel on design detail and manufacturing feasibility to achieve quality products, delivered to the trackside at the right time.

To enhance the launch support process, Executive Champions are appointed, 16 months before Job 1, to review progress with suppliers of key components or systems, identified as critical to the vehicle launch. These take the form of Supplier Launch Reviews targeting area of risk within the suppliers' own launch plans, and so requiring discussion on training, recruitment, facilities, tooling and sampling plans. Supplier Technical Assistance (STA) are responsible for supporting the Supplier Launch reviews as facilitators. As they have Jaguar Executive support the tendency is for the Supplier Senior Management to get involved, giving focus and much shortened decision loops.

This 'team' approach of supplier/manufacturer relationships ensures rapid response to change, with reduced costs and more robust plans to get the product to market on time. Through this the Suppliers are improving their own processes to meet our needs and therefore placing themselves in the best position for future business in the industry.

Electrical Proveout

Vehicle Electrical Systems are becoming increasingly complicated, new technologies have been introduced to meet demanding product specification and package constraints imposed by the low sleek style including multiplexed wiring and fibre optic systems with low and high speed communication networks. Although individual system functionality is generally understood and well defined, the system-to-system interactions are a new voyage of discovery each time. The Electrical Proveout can be conveniently divided into two areas of test work, Functional Testing and Measurement Testing.

Functional Testing:

This is a detailed test regime, which requires that systematic test procedures are written based on the Full Functional Specifications of each electrical system. These are then carried out to ensure that all aspects of each individual system is fully exercised. Additionally branch analysis is performed on all probable feed or earth paths to identify possible sources of interaction and these are incorporated into the test regime. All anomalies or unexpected events with regard to the whole vehicle generate an AIMS which must be resolved by establishing root cause and implementing containment with follow up permanent corrective action.

Measurement Testing:

These tests are carried out on parameters, which have historically been an issue. Here it is the voltage, resistance or current that is measured and compared to the expected results. The areas of general concern are usually quiescent current drain over time; lamp voltages, fuel consumption accuracy, fuel level and damping strategy and voltage drop across connectors and switches. Again detailed test procedures are written which allow accurate and comparable results to be obtained. With this series of tests there is more emphasis on car to car variability, but the resolution path through AIMS remains the same.

This systematic approach where every system on the car has its function fully exercised and all incidents reported and investigated is laborious as each vehicle will be subject to over 3000 individual tests and reports of 20 pages are often generated, but its value in preventing customer incidents is well proven. The issue which we have yet to resolve is as the complexity and interactivity of the vehicle systems grow then we need to supplement this type of testing with simulation analysis which is based on actual performance rather that design intent.

Drive Team Evaluations

Vehicles from later build phases are subject to rigorous evaluation. A team of assessors use a structured evaluation sheet from which they appraise each vehicle in a consistent way. The routes used will be the same for all vehicles and the sample number will be high as one of the objectives is to get a view of car to car variability. The assessment team is drawn from a number of different areas; its composition will be a mix of trained evaluators and project team members.

The vehicle is split into its Functional Image categories; each is assessed on a rating scale from 1 to 10. The results are analysed at regular Wash Up meetings where the results are compared to the program objectives and any specific issues will have AIMS raised against them

Field Evaluation Prototypes

A fleet of early build cars is allocated to various Senior Managers and Executives, which are run as normal day-to-day cars in lieu their normal vehicles. The placement is spread to provide the best coverage of all vehicle types and driving styles, some in the UK which allows good access for fault diagnosis, some in Germany where the average speeds are generally very high and some in the USA where they regularly travel for extended periods at constant speed.

These vehicles are used to simulate normal customer usage and a concern report must be raised as soon as an issue arises. In addition they must fill out a weekly questionnaire similar to the Drive Team documents that are used to gather more structured feedback, to compare against the drive team results and the program objectives.

The vehicles are returned to the launch team workshops for 1 day each week where measurements will be taken and normal maintenance checks carried out to assess if the vehicle is performing as expected. This allows any updates to be made where revised production parts have become available, the users then collect the vehicles and a feedback clinic is held where issues are discussed to establish their severity and the users may be requested to pay particular attention to certain areas.

All issues identified in this process are again resolved through AIMS.

Batch and Hold

Following the decision to authorise production ramp up into saleable cars, the cars are held in batches prior to dispatch. A NOVA-C audit is completed on a representative sample from each batch, any serious issues found in the audit are then used to construct an inspect and rectify list. The whole batch is now assessed against this list prior to being dispatched.

Conclusion

In summary, the way Jaguar launches New Products has become a strength rather then the weakness it once was, it is an iterative process, which seeks to build on the experience gained from the previous launches while continually attempting to eliminate the weaknesses. The over riding message should be that success is in the detail and if the daily routine is ignored then a poor result will follow.

Jaguar is no longer in the survival mode of the early 1990's, but has a sound business, poised for profitable growth over the next few years It is competing for the UK in very aggressive world-wide markets for luxury cars, but is very aware that a single poor product launch will undo the good progress made todate.

New Approaches to Managing Construction Projects

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NEW APPROACHES TO MANAGING CONSTRUCTION PROJECTS

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Abstract

In the construction industry, as with defence procurement, there is pressure from clients to deliver 'value', i.e. be cost effective and shorten product delivery times, i.e. a 'lean' approach. In addition (especially in the UK), there is a drive for contractors to deliver a 'service' over a specified period of years rather than just a physical asset (the building).

It is recognised that the key issue is getting the product right as early as possible – achieving early 'fixity' of design although this is not always possible as clients' needs may evolve and change throughout a project.

However, a number of recent initiatives (mostly client inspired) have been shown to provide a route to increased value and ability to manage clients' evolving needs.

These are:

1. Partnership agreements (long term relationships between client and contractors, rather than just on a project basis).

2. Multi-disciplinary project teams (client and contractor sharing the decision making).

3. Maximum standardisation of components and systems (reduction of design errors, more reliable procurement supply chains).

4. Structured approach to design decision making (tools to handle design dependencies) and to permit a concurrent design approach.

These ideas, with adaptation, should equally be applicable to defence procurement.

Introduction

It is well known that there have been many 'new' developments in manufacturing management practices over the last 2 decades (supply chain management, just-in-time, TQM, lean manufacturing, for example) which have been introduced to improve efficiency and effectiveness as a consequence of increasing global competition.

These developments were primarily initiated by and mostly implemented in industries such as automobiles and consumer electronics where there is the fiercest competition between worldwide brands and where products are manufactured on a large scale.

More recently, the construction industry has started to take up some of these ideas and adapt them to an obviously different 'manufacturing' industry situation with a view to improving the efficiency of the industry. The need for this is the same as for the generality of manufacturing – increasing global competition and consequently more demanding customers.

The evidence, so far, is that these ideas do have value in improving the construction process but that direct transfer from the automotive industry (which is what most people have tried to do) is not the right way. A better parallel is with aerospace. This aerospace 'model' when applied in the construction industry (another project type industry with, therefore, strong project management skills) can provide a useful set of experiences which may well be of value to defence procurement and project management generally.

The similarities between the construction and defence industries

Both of these industries have many similarities and both differ, significantly, from consumer products industries such as automotive:

- Customers are knowledgeable and will define functional requirements of the product and will frequently be involved in developing the technical specifications, devising the technical solutions and monitoring progress.
- Products are often 'unique' in that they are supplied in small volumes or, if in larger volumes, often with many variants.
- The design and development stage is a significant part of the supply process both in terms of its importance, its complexity and its

length. Customer involvement in this stage is usual.

- Individual units of product are of high value.
- Supply chains are frequently devised on a 'project' basis and often are short lived.

Current trends in the construction industry

Traditionally the industry has operated with a variety of, often complex, contractual relationships. The roles of client, architect, specialist consultant, quantity surveyor, main contractor and sub-contractors can vary between projects and can depend (in practice) on the relative skills, involvement and commercial strengths of the different parties. The allocation of risk between the parties is often not clear leading to a tendency for adversarial relationships. This is not helped by the low margins that contractors often work to and the financial resources needed for a major construction project.

Two serious investigations into the operation of the construction industry "Constructing the Team" (Ref. 1) and "Rethinking Construction" (Ref. 2) have highlighted the need for improvements in the traditional approach to construction management and, in the case of the Egan report, set quantitative targets to aim for.

These investigations reflected, in part, the concern that major clients (major property developers, retail and hotel chains, British Airports Authority and public sector procurement bodies in defence and health sectors) were not necessarily getting best value for money from their construction projects, as well as natural concern to have an efficient construction industry (it comprises ~ 10% of GDP in the UK).

Consequently, the major clients, together with some of the more far seeing contractors, have largely been responsible for introducing new ways of managing the construction process using manufacturing management experience suitably adapted to the construction industry.
Latterly also, there has been a greater emphasis on the whole life costs of a construction reflecting the fact that clients see a building or other installation not as an entity in itself but as a means of delivering a service over a long period (accommodation, a working environment or transport service, for example). This is leading, in the UK, to the Private Finance Initiative and similar mechanisms where a supplier is contracted to build, own and deliver a service over a period of years.

In such a situation there is added need for the client to get closer to the contractor, to develop a non-adversarial relationship and to work together to add value to the project as they have a shared interest in long term success.

It is not difficult to see the parallels between this and defence procurement. Hence, we can anticipate that these initiatives in the construction industry have relevance to defence procurement. Perhaps, also, there are new defence procurement ideas which could, with advantage, be translated to construction?

Examples of new approaches to construction management

I have taken 4 separate developments in construction management to illustrate the nature of the change occurring in the construction industry.

These different developments are not mutually exclusive, in fact they are complementary developments. Inevitably, of course, some contractors and clients have emphasised one or more of these rather than others. It is not sensible to introduce too many changes in a company culture all at the same time – we have all suffered from 'initiative overload'.

However, the common theme of all of them is improving the efficiency and predictability of the whole construction process.

1. Partnership Agreements This is a concept which originated in another 'project' type industry – i.e. oil and gas field developments on UK continental shelf. In the late 1980's – early 1990's, the fall in the oil price led to a need to reduce field development costs. Partnership agreements where the operators (the oil majors) entered into agreements with their major suppliers were a key factor in this cost reduction programme.

In return for a 'guaranteed' position as a supplier, a major contractor agreed to a share in the project risk (and reward if projects came in ahead of time and budget). Clearly this implied a non-adversarial relationship leading to a more efficiently managed project and lower project costs. This is an advance on the situation in, say, the automotive industry where major Tier 1 suppliers have long term relationships with the automobile companies and are expected to carry out and fund some of the product development work on new models.

Partnership agreements on the oil and gas industry model are beginning to appear in the construction industry. They are a necessary pre-condition for effective and credible multi-disciplinary teams.

2. Multi-disciplinary Project Teams This follows on from the partnership concept and seeks to include all relevant professionals as early as possible. It is well recognised that the cost and difficulty of making a design change increases exponentially as a project progresses (Ref. 3, for example, although there are many others). Therefore it makes sense to prevent this as far as possible. Co-located design teams which include client, architect and contractors have been found to work. Fig. 1 shows how the design decision making in such a situation compares with the more conventional approach.

A further example is the "Building down barriers" project where the project organisation for an MOD facility was structured into core and cluster teams This meets the dual need of overall, integrated control of the project together with groups concentrating on more specific aspects.

We might anticipate that IT developments will facilitate this and allow for effective teamworking without members having to be co-located. This is a future challenge and opportunity for the industry.

3. Maximum Standardisation and Pre-ssembly of Components and Systems This seems an obvious route to maximising construction efficiency but it has to be done without compromising an architect's freedom to design innovative buildings. A recent study (Ref. 5) has explored this issue and illustrates many case studies showing different degrees of standardisation and the associated issue of pre-assembly off site.

Clearly there has to be an element of standardisation in any case, if only at material and component level but the issue is how to optimise standardisation at the system or building module level but preserve the architect's freedom to design innovative buildings. Standardisation and pre-assembly can potentially lead to increased efficiency, higher quality (factory rather than site manufacture) and reduction of the amount of hazardous site work. There is a downside to this which is related to the nature of the construction industry. For economic off site pre-assembly and significant standardisation of systems and modules there must be an accurately predicted demand so that manufacturers can plan their operations. The early experience of 'system building' for UK public sector construction (houses, schools, for example) was not good in that there was little overall co-ordination of procurement. We now know much more about supply chain management and business processes so that, in principle, we can achieve the economic potential. Research into the relatively simple operation of constructing a concrete frame for a building (Ref. 6) has shown that attention to elementary supply chain management issues can reduce construction cycle time by 28%. This indicates the potential gains available.

As has been noted earlier, construction is a 'project based' industry with project specific organisation and supply chains. However, the major clients (utilities, hotel and retail chains, public sector bodies) can implement a more 'company' organisation and supply chain systems as they have a continuous construction activity.

An example is British Airports Authority which is operating a policy of standard specifications and preferred suppliers of construction items. There is no evidence that this need stifle innovative architectural design (though some architects might dispute this).

4. Structured approach to design decision making The client briefing and design stages (i.e. the pre-construction stages) are critical as errors and omissions at this stage are expensive and difficult to correct.

There has, therefore, been considerable effort to understand the design decision making process in construction, model it and then be better able to manage and monitor it.

Modelling of the design process analagous to the product realisation models developed in aerospace for example provides an understanding of the process at the abstract level but does not realistically map the highly iterative nature of design. By careful analysis of design decisions as they are made (Ref. 7) we can establish some generic facts about design decision making:

1. Irrespective of any other factors, the process of design decision making follows a characteristic 'S' curve when plotted against time on a normalised basis, although the parameters of the curve will vary between narrow limits as indicated by upper and lower bounds (Fig. 2).
2. More than 70% of design decisions at the system and sub-system level are common although the sequence can differ significantly. This sequence

difference can arise from a number of causes: little inter-dependence between decisions at this level, the highly iterative nature of the design process or the organisational structure (the relationship between the participants in the decision making process).

3. The most common drivers for design decisions are functionality, cost and interface issues.

4. Design on a 'day-to-day' basis is a highly iterative process not easily describable by structures which have a consistent relationship to the established 'macro' models of the design process which are used as high level abstractions to depict the major design output stages.

From this we can develop a simple 5-step guide (Ref. 8) to plan the design decision and timescale as a management /monitoring tool:

1. Identify the time-frame allowed for the design stage from initial client contact to design completion.

2. List the decisions to be made at system and sub-system level (typically 80-100 decisions for a building).

3. Produce a table of the number of decisions (not the actual decisions) against time in steps of 10% of allowable design time-frame.

4. Order the decisions in terms of the available skills, resources, information and constraints at the appropriate stages of decision/timetable.

5. Produce a final table of decisions/time-scale.

Ordering the decisions is the difficult step but there is now available a method of analysing and ordering the design dependencies for this purpose using the design-structure-matrix approach (Ref. 9).

Conclusions

This paper has illustrated the many similarities between defence procurement and construction projects. The competitive pressures on the construction industry and their ever more demanding clients have led to significant adaptation in business practice.

Examples of four areas where this has occurred (or is being addressed) have been discussed. They have been selected partly because the ideas would seem to be applicable also to defence procurement where there is a need to improve business processes for very similar reasons.

It has been found that direct transfer of practices across from manufacturing into construction is not correct. Ideas have to be adapted and amalgamated with the best practices in the construction industry, e.g. on project management. The same will occur if the ideas are applied to defence procurement.

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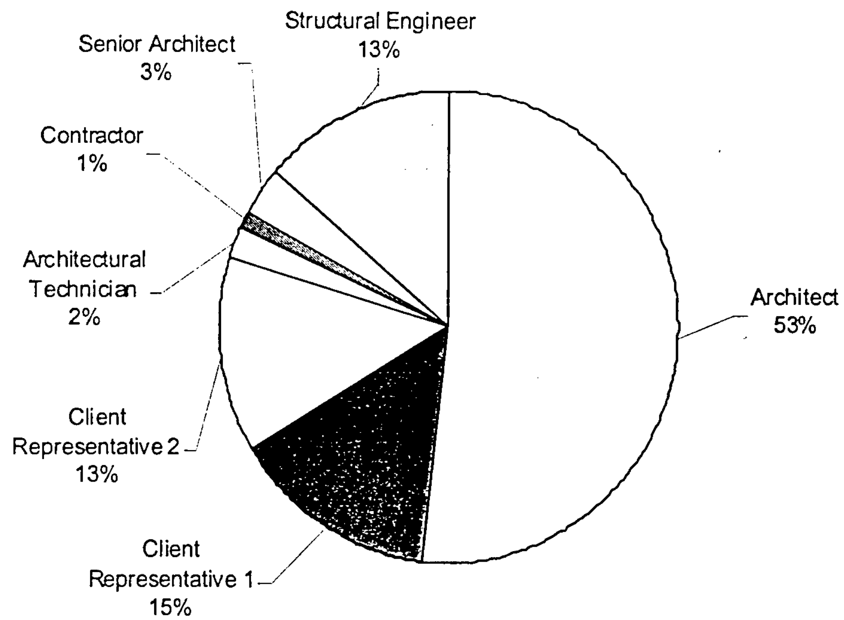

Fig. 1a: Who made the design decisions (traditional project)

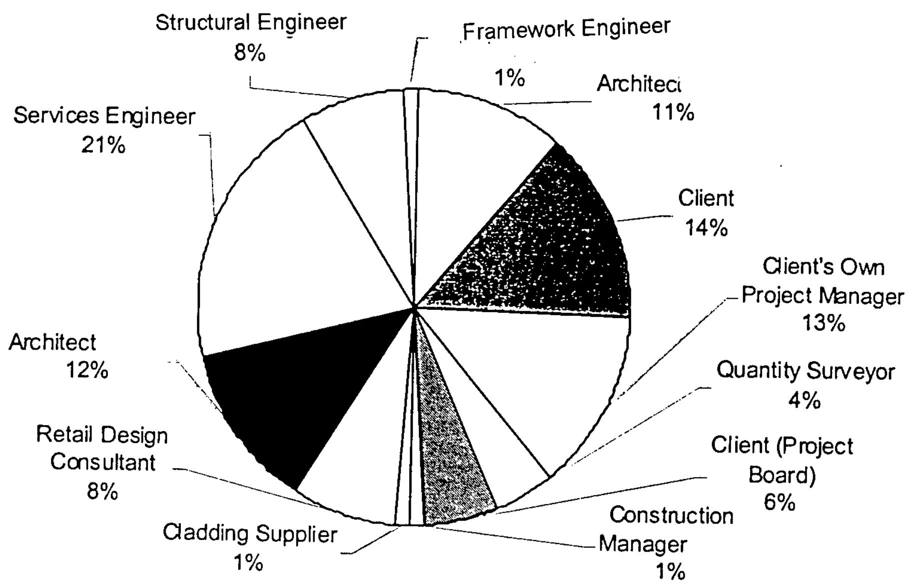

Fig. 1b: Who made the design decisions (team based project) (Ref. 10)

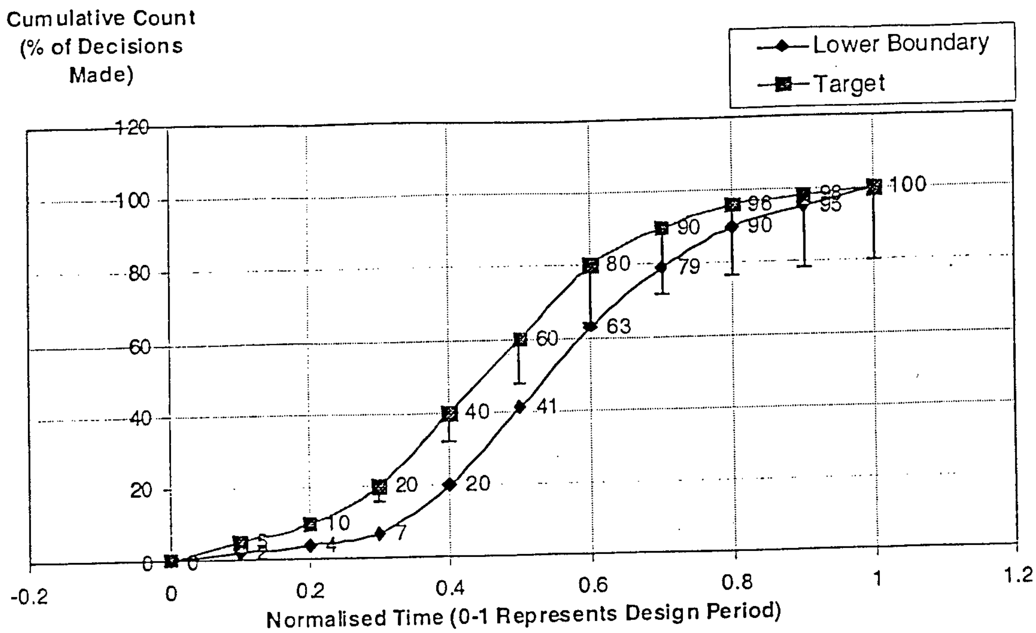

Fig. 2: Cumulative count of design decisions made against normalised time

Operational Impact Assessment of Wideband Tactical Communications: A Case Study

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The Scope/Cost Process of Wideband Tactical Communications, A Case Study

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Abstract

The United States Air Force Operational Test and Evaluation Center (AFOTEC) is now conducting Operational Impact Assessments (OIA) of certain Department of Defense (DoD) Mission Areas in order to inform the appropriate warfighting Commanders in Chief (CINCs) of the mission impact of operating a new weapon system in the field. AFOTEC has taken this additional responsibility to increase the value of our test reports. The evaluation methodology for conducting both operational testing and OIAs is called the Scope/Cost Process (SCP). This methodology is a five-step process: 1) System Introduction, 2) Understand Battlefield Operations, 3) Operational Risk/Impact Analysis, 4) Develop and Cost OT&E Options, 5) Option Selection and Tasking. AFOTEC is currently test planning Wideband Gapfiller Satellite (WGS). Along with an evaluation of the system's operational effectiveness and suitability during the Multi-service Operational Test and Evaluation (MOT&E), AFOTEC will conduct an OIA on how WGS supports the operational tasks. This paper explores the SCP process for Wideband Tactical Communications.

Paper

1.0 Background.

AFOTEC has been designated by the DoD as the lead operational test agency for the Wideband Gapfiller Satellite (WGS) System. As such, AFOTEC developed a strategy for operationally testing WGS and its operational interfaces. The methodology used to develop an evaluation strategy to test weapon systems is called the Scope/Cost Process (SCP). While it encompasses the traditional system-level initial operational test and evaluation (IOT&E) which determines system operational effectiveness and suitability, SCP also includes an assessment of how a new system interacts with the entire operational battlespace. For WGS, the IOT&E will be a multi-service OT&E.

2.0 Scope/Cost Process.

The SCP process consists of five steps which produce an evaluation strategy which culminates in a Tasking Order (TO). The designated test team uses the evaluation strategy to develop a test concept. The five steps are: 1) System Introduction, 2) Understand Battlefield Operations, 3) Operational Risk/Impact Analysis, 4) Develop and Cost OT&E Options, 5) Option Selection and Tasking. Step 1 is to gather design, performance, and system employment information about the system under test. In order to carry out step 2 (understand battlefield operations), the SCP team consults experts from major commands, unified commands, and joint commands; and studies military doctrine. To focus the analysis, a particular mission area is selected. Step 2 could extend a long period because of the breadth of information available, but is usually limited by the demand for a TO (Step 5). Step 3 is an analysis to determine what failures have the most impact to the mission. Steps 2 and 3 flow together to produce the OIA questions as depicted in Figure 1. AFOTEC does not have the resources to answer all of the OIA questions so step 4 is required. Step 5 results in a Tasking Order (TO) which is signed by the Vice-Commander. The

TO directs the designated test team to initiate detailed test planning. The test team will then develop a test plan to conduct the IOT&E and answer the selected OIA questions.

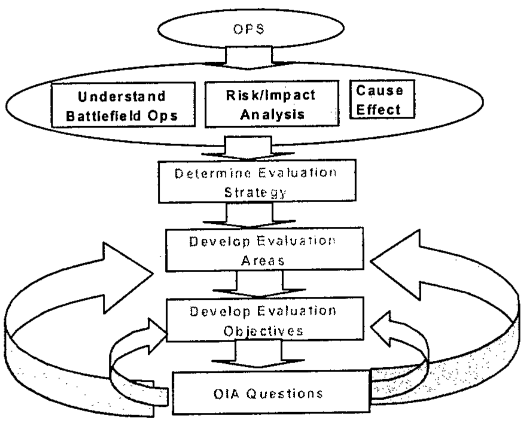


Figure 1. OIA Flow.

2.1 System Introduction.

Once launched into geosynchronous orbit, the Wideband Gapfiller Satellites will become a part of the Wideband Satellite Constellation which includes the Defense Satellite Communications System (DSCS), Ultra High Frequency (UHF) Follow-on (UFO) communication satellites and the Global Broad Service (GBS). The WGS will be controlled by the existing DSCS Operations Center (DSCSOC). The WGS will use two frequency bands: X band and Ka band (One way Ka for GBS and 2-way Ka for other communications).

The WGS primarily supports deployed tactical forces but must also be capable of supporting strategic and tactical nuclear missions areas. WGS supports the following DoD designated mission areas:

- Strategic Offense
- Strategic Defense
- Land Warfare
- Air Warfare
- Naval Warfare
- Theater Nuclear War
- Inter-Theater Airlift
- Inter-Theater Sealift
- Intra-Theater Airlift
- C3I Programs
- Special Operations Forces
- Strategic Command, Control, and Communications (C3)
- Strategic Command and Control (C2)
- Strategic Surveillance and Warning
- Strategic Communications
- Theater and Tactical Programs
- Theater C2
- Tactical Communications
- Navigation/Warfare C2
- Land Warfare C2
- Air Warfare C2
- Naval Warfare C2
- Theater Nuclear C2
- Support & Base Communications
- Long Haul Communications
- Space Launch Orbital Support
- Weather Services
- Non-DoD Communications.

To make the SCP process manageable, the mission selected was Special Operations Forces in step 2. Any of the above tactical missions could have been selected, however, the Special Operations Forces mission had previously been expanded by another AFOTEC team (CV-22).

2.2 Understand Battlefield Operations

Figure 2 illustrates the Joint Operational Requirements Document Special Operations Forces (SOF) Mission Profile Key Performance Parameters (KPPs). The CV-22 team came up with the following mission breakdown:

- National Goal: Ensure Liberty for all United States (US) Citizens.

- National Security Objective: Defeat Aggression.
- National Military Objective: Defeat Regional Aggression.
- Regional Objective: Defeat Unconventional Threats to US Citizens and Interests Overseas.
- Operational Objective: Retrieve Military Personnel in Distress.
- Operational Task: Recovery of Isolated Personnel.

An operational task is defined as a specific event on the battlefield.

For WGS, the mission breakdown focused on expanding the support element of Wideband Tactical Communications within Special Operations Forces. Wideband Tactical Communications was broken down into the following functional elements:

- Planning (Deliberate/Crisis)
- Force Generation and Direction
- Situation Monitoring
- Network Modification
- Force Management.

Each function was then defined as either a mission element or a support element. See Figure 3.

Additional information was gathered on Wideband Tactical Communications, but will not be discussed here due to time and space limitations.

This step establishes what is necessary to accomplish an operational task. The next step determines what is sufficient to accomplish an operational task. Both are required for an operational task to succeed.

2.3 Operational Risk/Impact Analysis.

The next step is to analyze the operational risk or impact to adding the system under test (WGS) to the battlefield. This analysis is a four step process which looks at each element in the mission decomposition (expansion):

- Element impacts on operational task (mission).
- Element impacts on other elements.
- Element(s) impacts on the system (WGS).
- System impacts on the element(s).

See Figure 4. Next, a Cause Effect analysis was accomplished. Cause Effect is done by looking at the operational task (Recover Isolated Personnel) and work backward determining all the possible failures that could occur which would prevent the accomplishment of the operational task. This analysis helps the team develop an evaluation strategy (see Figure 1) by focusing on what areas have the most impact on mission accomplishment. These focus areas become the evaluation areas for the OIA. From the evaluation areas come the evaluation objectives. Next, questions were developed which the test team could answer during test execution. The answers to selected OIA questions (as determined by the final two steps) will be documented in the WGS MOT&E Report.

For WGS, the Evaluation Strategy is the following:

- Use the SCP to ensure test program is cost effective and provides relevant information to the Combatant Commands.
- Maximize exercise participation within the constraints of time and resources.
- Maximize data collection from combined testing with the developmental test (DT) community.
- Minimize time required for the dedicated MOT&E.
- Eliminate AFOTEC testing of specification level requirements (Ensure the DT community will cover).

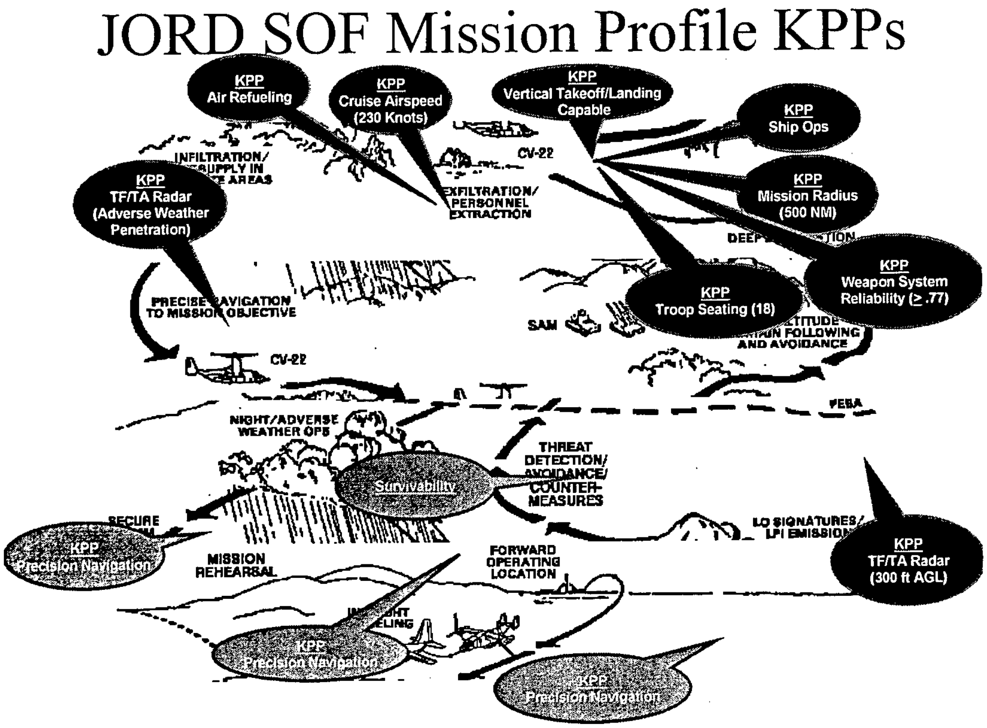


Figure 2. Joint Operational Requirements Document Mission Profile Key Performance Parameters (KPPs)

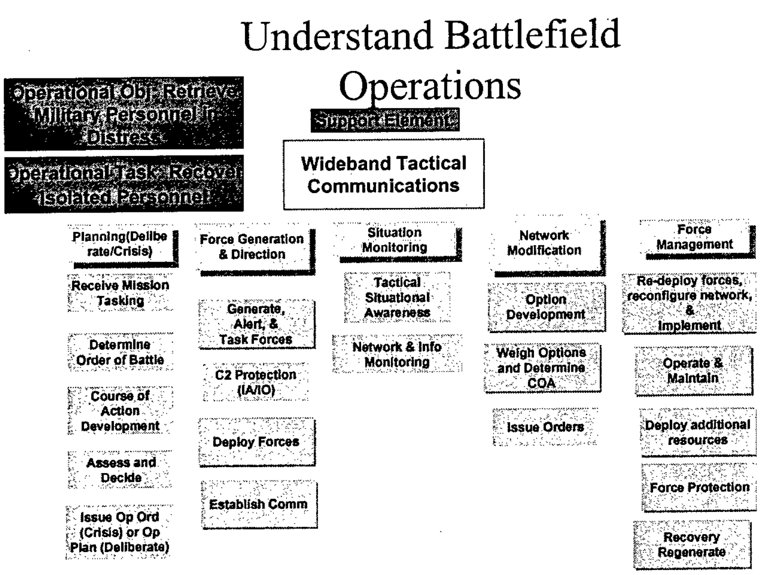


Figure 3. Understand Battlefield Operations

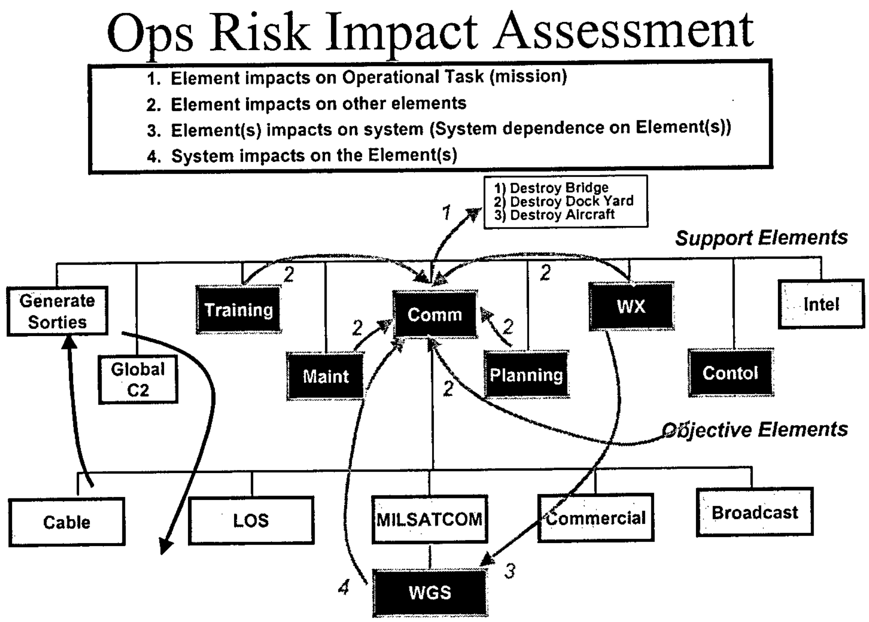
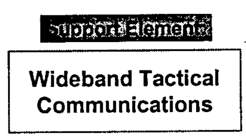


Figure 4. Operational Risk/Impact Assessment



- •Is there adequate comm?
- •Is comm available to support dissemination of ATO's?
- •Can comm handle the load and time restraints (WX, Intel, Mission Planning...)
- •Is secure comm available?
- •Deter/counter Info Warfare attacks?
- •How long to set up to initially support theater operations?
- •Allocation of comm assets?
- •Is the comm timely and sufficient?
- •Is the jamming protection adequate in an hostile environment?
- •Is the jamming protection adequate in environment of "friendly" jamming?
- •Are the tactical terminals easily transportable in the theatre?
- •Are the tactical terminals ruggedized for the theatre?
- •Can the tactical networks be efficiently and effectively configured real time in theatre?

Figure 5. Sample of OIA Questions for WGS

The Evaluation Area is: Timely communications (via satellite) to tactical units in the field.

The Evaluation Objectives are:

- Communication Planning/Managment
- Communication Performance
- Communication Access
- Susceptibility.

Some of the OIA questions are listed in Figure 5.

2.4 Develop and Cost OT&E Options.

The next step is to develop and estimate costs for different test options. The AFOTEC Director of Operations will review and determine the best alternative considering the resources (manpower, money, time) available. AFOTEC has a priority list of programs based on Major Commands priorities, the size of the program, and the value of operational test information to the CINCs.

The Director of Operations also determines what products the test team will produce. For WGS, the test team will produce:

- Early Operational Assessment (EOA). Both program information and early OIA information will be included. This is due to the Milestone Decision Authority by Aug 00.
- Operational Assessment (OA). Additional OIA information and the program issues affecting testing will be included. Due to the DoD Director, Operational Test and Evaluation (DOT&E) after the WGS Critical Design Review.
- MOT&E Report. Will contain the OIA results plus answer whether the WGS system is effective and suitable. Due to the Major Commands before the WGS Initial Operating Capability (IOC) decision.

2.5 Option Selection and Tasking

The final step of the initial SCP process is option selection by the Director of Operations. This is documented by a Tasking Order which is signed by the AFOTEC Vice Commander.

3.0 Summary.

The SCP process is a methodology to ensure AFOTEC gives the Combatant Commands relevant information. This information is given before a new system is deployed, thus allowing the CINCs to decide how to use a system for maximimum effectiveness and suitabilty.

4.0 References.

1. AFOTECI 99-101, Business Management Process, AFOTEC, 20 Jan 00.
2. AFOTECI 99-102, Operational Test Product Delivery Process, AFOTEC, 20 Jan 00.
3. Joint WGS Concept of Operations, HQ USSPACECOM, 13 Dec 99 (Draft).
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The Increasing Use of High Speed Digital Imagery as a Measurement Tool in T&E

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THE INCREASING USE OF HIGH SPEED DIGITAL IMAGERY AS A MEASUREMENT TOOL IN T&E

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Abstract

Photography's inestimable contribution to science and technology is beyond question. Applied photography is that area of work which assumes an integral part of a research project and where the results of photographic analysis form a major source of information.

In military research and development or testing there are various fast and dangerous events that need to be recorded and analysed. High-speed cameras allow the capture of movement too fast to be recognised by the human eye, and provide data that is essential for the analysis and evaluation of such events. High-speed photography is often the only type of instrumentation that can be used to record the parameters demanded by our customers. Examples are shown and discussed where this applied cinematography is used not only to provide a visual record of events, but also as an essential measurement tool.

Whereas traditionally silver-based photographic films were the only recording means available, nowadays a variety of other sensors are used. This paper shows actual film records from a variety of weapon tests, highlights the increasing use of electronic recording media, and introduces the strategy of completely "digitising" optical recording on our ranges in the near future. Although many of the techniques discussed have been developed specifically for armament testing many of them are equally applicable to other industries.

Introduction

Almost from the birth of photography film has been used as the recording medium at our test sites during research and testing experiments. Colonel Shrapnel was conducting his studies into fragmentation at our site at Shoeburyness in the first half of the 19th century – and almost certainly would have used photography to record the results if it had been invented then. Shoeburyness has been a military test site since 1849, which is about the same time that photography as we know it was discovered.

Shoeburyness is one of our four Land Environment Ranges. We have five Air Ranges and 12 sea Ranges (although some of these are very small facilities). These divisions of Land, Sea and Air are likely to disappear in the near future.

I intend to show examples of how photography has been used as an essential data-gathering tool over the years, and why we are now moving away from film based systems to electronic digital imagery. A colleague of mine gave a paper on the history of optical trackers at the last (3rd) Test & Evaluation Forum two years ago, so I do not intend to repeat any of that subject. Trackers, and their associated photography, are largely confined to the Air Ranges. My examples are largely drawn from the Land Ranges Environment and in particular from our site at Pendine, where I was Operations Manager for four years. Pendine is the centre for our test track work and high-speed cine photography is of particular importance in that application. However I must stress that the techniques discussed can, and are, universally deployed at any of our range sites.

Background

With its unique capability for expanding time, "freezing" motion, and accurately recording distances and angles, high-speed photography in all its many variants has established itself as an extremely valuable measurement tool in the testing and development of weapons and armaments. Pendine has existed as one of our prime testing sites since 1940 where the 11km

beach forms an integral part of the testing facilities. This beach has of course been famous since the 1920's as the site for many attempts on the land speed record, with Malcolm Campbell, Parry-Thomas and Foresti all pushing the record faster and faster in the hectic period between 1924 – 1930. I will return to this topic later. The 1500m Long Test Track was built there in 1956 during the heyday of the UK guided weapon development. Our main customers have always been largely from MOD and the defence industries, but we have on occasions, and increasingly nowadays, done work for purely commercial customers. For example here the test track is being used for investigation of side wind loading on a scale model of British Rail's ill-fated Advanced Passenger Train. The great variety of comprehensive testing facilities that exist on our sites cover work ranging from arena trials of fragmenting warheads, standard fuel fire hearth tests, shaped charge investigation work which includes a lot of flash radiography instrumentation, to small arms development, testing and proofing. However by far the greatest demand for high-speed photography is generated by trials using one of the three test tracks. We have a short 200m track largely used for dynamic proofing of warheads: a 400m high G impact test track originally built for testing nuclear transportation flasks; but our main and more challenging workload is photography of trials on the unique (to the UK) 1500m long test track. Since its original usage the track facilities have been progressively expanded to cater for a wide variety of different trials which include:

- Terminal ballistic trials and proof firings of warheads against a range of aircraft, missile and plate targets.
- Testing of proximity fuzes against targets at operational velocity.
- The study of flight characteristics of aircraft ejection seats and instrumented dummy behaviour.
- The study of submunition ejection and separation from airborne dispensers.
- The assessment of the performance of aircraft missile warning systems.
- Rain erosion trials of radomes, nosecones and other such materials.
- The study of wire dispensing systems and high-speed parachutes. This includes the use of on-board sled cameras.
- The study of the ejection and flight of IR flares and chaff decoys.
- And latterly the work has concentrated on the penetration performance of aircraft bombs and missiles against representative concrete targets.

In all this type of work the first and foremost reason for using high-speed photography is to allow design engineers and scientists to "see" these fast, transient, often dangerous and unpredictable events, in order to simply assess behaviour and make informed qualitative judgements. These are often all that is required in order to progress to the next stage of the experiment. High-speed photography not only provides these quick look results but also gives a permanent record for subsequent detailed analysis and measurement. One advantage of the move to digital techniques is that it will allow much quicker, almost instant, access to these results without waiting for films to be processed. It will also allow for basic computational analysis actually on the firing site.

Examples

I will now show a series of results using actual film clips from various trials and explain what the high-speed cameras were deployed to measure.

Three or four years ago we were asked to record the performance of a 90mm dense metal penetrator against reinforced concrete targets. The critical factor here was the impact angle was not to exceed the design parameter of 2 degrees. The store was released into free flight at the end of the test track by an explosive bolt technique, which meant that the impact angle could not be tightly controlled, so this had to be accurately recorded for each of the fifteen firings.

This camera shows the pitch angle and also allows impact velocity to be measured by the inclusion of a calibrated scale, which is surveyed in horizontally on the flight line. The camera was running at 12000pps and the impact velocity was measured off the films of the various firings as between 375 and 450 metres per second (m/s). On two firings the recorded pitch angle exceeded the criteria of 2 degrees, one being measured as 6 degrees nose down, the other being 3.5 degrees nose up. These firings had to be repeated.

This camera recorded the yaw angle, again running at 12000pps, by looking vertically down upon the event from a 10m high gantry. On all firings the yaw angle never exceeded the required 2 degrees.

Another important parameter that the customer required us to record was total penetration time through the target. This could have been achieved by timing the rupture of two foil switches electronically, but as they also desired to see target behaviour, and record exit angle and velocity, we used high-speed photography to record all desired parameters. This camera ran at 10000pps and by utilising the 1kHz calibrated time base routinely recorded on the edge of every film penetration time intervals ranging between 7 to 10.5ms were measured. In total we had eight cameras viewing different aspects on all fifteen firings. Frame rates varied between 6000 and 15000pps depending on the area under study. Besides angular and velocity measurements tumble and spin rates were also calculated from the film records.

A similar trial but on a much larger scale was carried out recently on the long test track to study the penetration properties of various configurations of aircraft bombs. On these firings many of the requested measurements were similar to those just mentioned, such as pitch and yaw angles at impact, as well as flight behaviour and velocities. Again high-speed cine cameras not only allowed the recording of what happened, as all evidence is of course destroyed by the very nature of the experiment, but also provided the basic data from which these measurements could be calculated. In all 11 cameras were deployed looking at different aspects of the impact and target reaction.

This camera recorded general flight behaviour at impact by running at 1000pps, whilst this one running at 3000pps gave a closer view of impact from 90 degrees to the line of fire (LoF) for pitch angle and impact velocity measurements. This one again on a 10m gantry recorded yaw angle and a second check of velocity.

One particular request on these firings was to record a deceleration profile of the bomb during penetration of the target. By running a camera at 20000pps we hoped to provide enough data points for this to be analysed and plotted. On the first firing it was immediately apparent that debris obscured the bomb during much of the penetration phase. So we added this carbon fibre extension piece to the tail of the bomb in order to prolong the time it was visible and hence increase the data recording time. This was moderately successful but even running at 20000pps was not providing enough data points for accurate computation, especially at the higher velocities.

By using streak photography, that is utilising the fact that in a high-speed camera the film is in continuous motion past the gate rather than being stationary at the time of exposure as in conventional motion picture cameras, we produced this record of the bomb impact. This is basically a distance versus time graph drawn directly on film thus allowing subsequent analysis and graphical presentation if necessary. The datums are produced by fixing on to the bomb body two small reflecting spheres and illuminating them with conventional photographic lighting during the impact phase; thus effectively producing point source datums. Illuminating spots of highly reflective material accurately placed in the field of view (FOV) similarly produce scales.

The classical use of streak techniques is in the accurate timing of short duration self-luminous or high contrast events. The accuracy and certainty of recording these events is of course due to the continuous recording ability due to the lack of any dead time between subsequent exposures inherent in any framing camera regardless of its frame rate. This slide shows the operation of two exploding bridge wire (EBW) detonators in a new design of electronic fuze. The time interval between the two functions was measured directly off this film as 300 microseconds. The fact that the fuze was travelling down the test track at some 700m/s made the synchronisation of the event to the camera running time somewhat difficult. However the film does not have to be run very fast through the camera with this technique, even to record microsecond timings, thus giving a comfortably long recording time. I am talking here about using film cameras with the optical block removed for this type of application. Time resolutions in the nano and pico second range, even out to femtosecond resolution, demand the use of very specialised electronic image tube cameras manufactured for this particular purpose and thus very expensive. The streaking in the background of this example is of course caused by the forward motion of

the carrier vehicle and can be used to measure velocity by calculating the angle of the FOV and the time taken to cross it. It makes such measurements much easier if a distance scale is introduced into the FOV so allowing a time versus distance computation of velocity to be made directly off film.

This slide shows a static shaped charge explosion with such a calibrated distance marker allowing a jet tip velocity in excess of 10000m/s to be measured.

Another often used application of streak photography is in post-impact delay work, where it is necessary to record where and when a shell explodes behind a target. This slide shows such an event in a multi-plate target where the edges of each plate have been enhanced with reflective material and illuminated to produce the scale.

Steak photography is of course non-pictorial. By using a similar de-blocked camera but this time running the film parallel to the event plane, we employ what has become to be known as ballistic-synchro photography. This produces a highly detailed single shot still photograph of fast moving objects. This technique has been historically used for many years to record bullets, shells and projectiles in flight in order to image such details as rifling marks, driving bands, sabot separation, etc. It is often accompanied by a somewhat bastardised schlieren technique for visualising shock waves. This slide shows how we met one particular requirement which was to show the effect of ejecting sub-munitions into a supersonic airflow at a velocity of Mach 2.5 (850m/s).

This technique is not really used for measurement purposes but more for imaging detail with great clarity and resolution. However aerodynamacists can calculate velocities from the angle of the shock wave. If three cameras are deployed in surveyed positions along the trajectory and the projectile suitably marked then spin rates can be determined. A similar technique is used for horse race and athletic photo-finish cameras where continuous recording is important – but these subjects are moving a little slower than bullets!

We have been involved in a large programme of research work over the last 8 to 10 years or so investigating the effect of small fragments on aircraft structures. This was concerned both with fragmenting missile warhead design and the effect of terrorist bombs on board civil aircraft. Early in this programme it soon became evident that conventional recording techniques would be inadequate to provide the detailed records required. This was particularly so with recording the impact angle of small 6mm cubes with velocities in excess of 2000m/s. We were soon made aware of the very real problems of attempting to record very small high velocity subjects and the limitations of conventional high-speed cine techniques. To overcome these problems we initially illuminated the cubes in flight with a pulsed copper vapour laser to give very short exposure times in the order of 20 nanoseconds (ns). Even filming at 20000pps the magnification required only gave us three frames of usable information. One particular advantage of laser illumination, besides its short duration and high light levels, is its monochromaticity. By using narrow cut filters all ambient light can be eliminated including the kinetic energy flash. This slide shows the clearer image thus obtained.

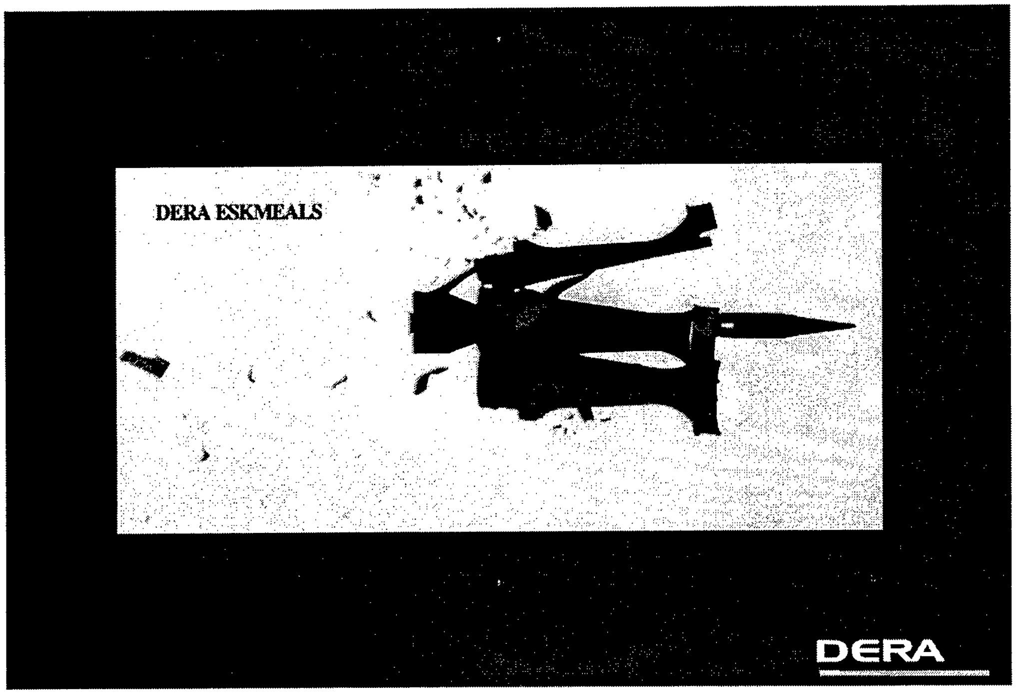
These limitations very graphically showed the shortcomings of conventional high-speed photography in such situations, and led us to consider the then new methods of electronic imaging.

By using an image converter tube camera running at the equivalent of 1 million pictures per second with 200ns exposure times and 3ns between frames these pictures were obtained, allowing not only impact angles to be measured but also spin rate.

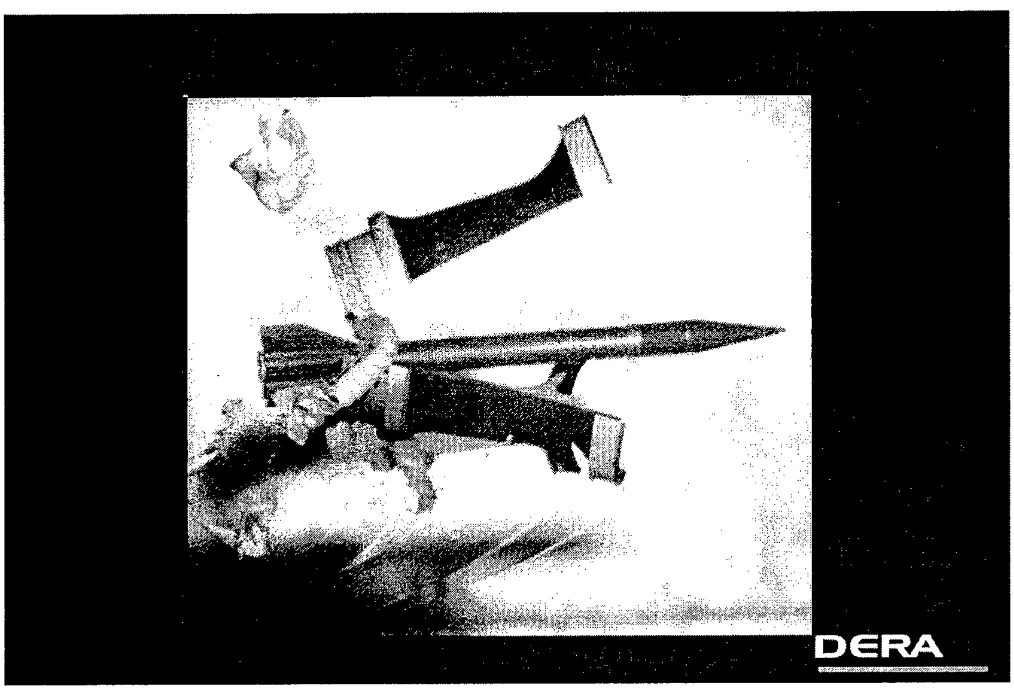
It became necessary during the progress of this prolonged research, which is still ongoing, to ascertain with even greater accuracy the impact angle: as it was discovered that this had a significant effect on subsequent target damage. At the same time the electronic imagery capabilities were moving on apace. These pictures were taken with an electronic digital imagery camera specifically designed for ballistic range work, the development of which we had helped with. They allowed us to measure the impact angle in detail but also to look at behind target effects; and with a double exposure technique to measure impact and fragment velocities.

The use of these electronic imaging cameras has now become extensive in our type of work. This slide shows there ability to show rifling details on a 30mm round; and this one

shows the pitch and yaw angles of a 20mm round simultaneously by using a 45 degree angled mirror in the FOV above the flight line. These cameras advantages are now invaluable during such trials as these which need many firings to replicate unpredictable and spurious events. The use of such cameras eliminates the exposure and processing of many hundreds of feet of film; and there instantly available record, with on site basic computer analysis, means that they have become very useful measurement tools. We have six within ranges sector. A colour version is now available. Although these particular cameras produce only one still picture, albeit with multi-exposure facilities if needed, the same technology is now being applied to the development of framing cameras. This is what drove the strategic decision to go totally digital and over the next two or three years to replace all our film cameras with digital high frame rate video cameras. Because the technology is aligned to the consumer driven amateur digital stills market it advances at a remarkable pace. Ultimate resolution does not yet quite match that of film, but I have every confidence that it will in the very near future. This meant that we can dispense with all our film processing facilities, with the consequent environmental and cost saving advantages. We will then be able to offer our customers a more versatile, speedier, state of the art solution to their imaging and analysis requirements; so making the decision to go digital both inevitable and of sound business sense.



155mm FSAPDS Ammunition – Film Image



155mm FSAPDS Ammunition - Electronic Image

Multi-Influence Underwater Measurement and Airborne Detection

Dr G Webb, Defence Evaluation & Research Agency, UK

MULTI-INFLUENCE UNDERWATER MEASUREMENT AND AIRBORNE DETECTION

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Abstract

DERA T&E Ranges has, amongst other things, responsibility for measurement and control of the underwater signatures of warships. Recent developments have extended the capability of degaussing ranges from measurement of magnetic fields alone to electric and pressure with confirmatory checking of acoustic signatures too. The electric field measurement is by a novel method using modelling from the electric potential which permits far easier deployments of the transportable range than would be possible if the field itself was measured. One consequence of the electric field of certain vessels is the magnetic field from the electric current which results from the presence of an electric field in seawater. Since the electric fields from vessels are a result of corrosion, the magnetic field from this cause is known as the corrosion related magnetic (CRM) field. The CRM field is significant as it decays more slowly with distance than the magnetic field from magnetic sources. Therefore, it offers the possibility of a greater range of airborne detection. The new multi-influence ranges provide prediction of the airborne magnetic field from both electric and magnetic sources. The range design allows the fixed and transportable ranges to be functionally identical so measurements in various parts of the world can be compared directly. The ease of deployment of the transportable range means it is simpler to take the range to the warships than bring the ships to the range so international collaboration is simplified. Within a month of acceptance of the system vessels of the Royal Netherlands and Belgian Navies had been ranged in addition to British Royal Navy vessels.

The range systems are described together with the algorithms and software and their empirical validation.

Introduction

Ships and submarines may be detected in several ways by the electromagnetic fields they emit. This paper is mainly concerned with in-water fields and their detection. Because of the rapidly increasing attenuation of electromagnetic radiation with increasing frequency, we are mainly concerned with frequencies below 3kHz. Of course, in air, vessels on the surface emit frequencies much higher than 3kHz (for example communications radio and radar) but these travel only a very short distance in seawater so are not a means of underwater detection. Submerged submarines do not emit radio and radar signals (except when an antenna is deployed on the surface deliberately) so only low frequencies are of interest. The measurement of the underwater electromagnetic emissions from vessels is necessary to ascertain whether faulty equipment (which could be fixed) is causing excessive levels, to evaluate the threat from mines and other detection devices and to enable the setting up of any countermeasures which may be used.

Some Definitions

Electromagnetic ranging has been a development of *degaussing* ranging, so the nomenclature used to describe the various fields and bandwidths has developed from that used in the degaussing community.

The term degaussing applies to methods of reducing vessels' magnetic fields by applying electric currents to degaussing coils fitted within the vessel to generate a magnetic signature (the magnetic field below the vessel) which opposes the magnetic signature of the ferromagnetic material in the vessel. Some vessels become permanently magnetised such that demagnetisation is necessary. This is generally known as magnetic *treatment* and requires the application of magnetic fields externally to the vessel by means of large coils (several hundred metres on each side) on the seabed, large structures which are big enough to enclose the entire vessel bearing coils or closely wrapping substantial coils around the vessel.

The signature affected by magnetic treatment and degaussing is known as the static magnetic field (since it does not move with respect to the vessel). However, since the vessel moves with respect to the seabed (where a range or a magnetic mine sensor might be), the static signature does vary with time but with a maximum bandwidth not exceeding a few hertz. Detection of these fields from the vessel are in the near field so the equations which best describe the propagation of the field from the source are the near field equations and not the radiation equations. An interesting consequence of this is that no energy flows from the vessel in producing a magnetic field at a distance unlike the alternating electromagnetic fields (see below) and the acoustic emissions. (For example at 1Hz, the wavelength in air is 300km. There is insufficient power in frequencies in this region for vessel detection at anywhere near this distance.)

Rotating equipment and alternating power frequencies also produce magnetic fields, but since these are time-varying with respect to the vessel they are known as dynamic or alternating fields.

Corrosion of the vessel due to different metals used in its construction (for example the steel hull and phosphor bronze propulsors) results in a static electric field in the seawater. This field, like the static magnetic, only extends up to a few hertz but it can be modulated by the rotation of a propulsor (for example, by the electrical resistance of the electrical path between the shaft and the vessel through the shaft bearings) and this produces higher frequencies. In addition, active cathodic protection devices (which operate by forcing a current through anodes which opposes the corrosion current) often have power harmonics present resulting in higher frequencies being emitted. Collectively, the electric field from time-varying sources on vessels is known as the alternating electric field.

The generic name for all the underwater electromagnetic fields is ELFE (extra low frequency electromagnetic).

Finally, an electric field cannot exist in seawater (a conducting medium) without an electric current also being present. An electric current is always associated with a magnetic field, so an additional component of the magnetic field is produced by the corrosion current. This is known as the corrosion related magnetic (CRM) field.

Degaussing Ranges

Traditionally, degaussing ranges consisted of ten or more underwater magnetic sensors at a typical mine threat depth (9 to 30m). Data collection was by galvanometer deflection and photographic film or chart recorder. Degaussing coil setting was by successive approximation, needing a separate pass or the vessel over the range (a *run*). Some vessels have as many as eighty-two degaussing coils so the number of runs necessary to achieve a satisfactory magnetic signature could take many hours. In many areas, there is significant tidal change over a period of hours so the measured signature can vary by a factor of two or more. Furthermore, the vessel was unlikely to pass exactly the same distance from the nearest sensor on successive runs further complicating the analysis.

In recent years, computer development has allowed algorithms of some complexity to be run on processors which are within the budget of degaussing range operators. As a result, the number of underwater sensors has tended to decrease and magnetic modelling of the magnetisation of the ranging vessel has been used to simulate the additional sensors necessary for interpretation of the data. Modelling also removes the variations caused by measurement at different depths and different distances from the nearest sensor. In the UK, infra-red tracking, and more recently, real time kinematic differential GPS (RTKDGPS) has provided vessel tracking to an accuracy of approximately 7cm.

The UK Magnetic Ranges

All the UK degaussing ranges were replaced by three-axis, five-sensor, computer modelling ranges approximately ten years ago. Five years ago, the ranges were upgraded to the present software configuration. Generally, the ranges have performed well, with repeatability of typically 1% or so. But, on some occasions, anomalous results were obtained. The CRM field was thought to be responsible but separation of the CRM from the ferromagnetic field is error prone because the CRM is usually much smaller than the ferromagnetic field at degaussing range measurement distances. The proposed solution was to measure the electric field and calculate the corrosion currents and hence the CRM field from it.

The UK degaussing ranges are located at Portland, Plymouth, on the Clyde and on the Forth. There is also a transportable range which can be deployed at short notice anywhere in the world. The transportable range uses identical equipment to the fixed ranges which ensures commonality of measurement results.

One of the benefits of the transportable range is the ease of deployment of the sensors. They weigh only 12kg (in air) and can easily be deployed by divers using an inflatable boat. Electric field sensors usually consist of between four and six electrodes separated by between 30cm and 2m. If electric sensors were to be added to the range, a considerable increase in the weight of each sensor would result with a consequent increase in the difficulty of deployment.

If the electric potential could be measured, only a single electrode need be used at each sensor position and no decrease in the ease of deployment of the transportable range would result.

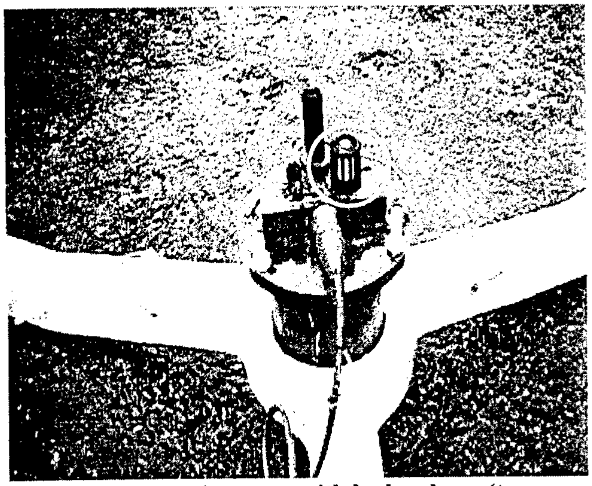

Figure 1 A magnetic sensor with hydrophone (top, rear) and single electrode (circled, upper right)

Figure 1 shows a range sensor on a transportable range tripod. On the top of the sensor are a hydrophone (the tall extrusion at the back, an electric potential sensor (circled) and a pressure sensor which is present on nearly all our magnetic sensors. The sensor enclosure is approximately 40cm high and 25cm diameter.

Static field modelling

The use of modelling techniques in magnetic ranging has been described elsewhere (Ref 1) so it will only be summarised here.

Any magnetic source, no matter how complicated, can be represented as a collection of magnetic dipoles. The magnetic field, **B** (actually, **B** should be referred to as the magnetic flux density but it has become conventional in the degaussing community to refer to the magnetic field), from a single dipole of magnetic moment, **M** is given by:

$$\mathbf{B} = \frac{\mu_0}{4\pi}\mathbf{D}.\mathbf{M} \qquad (1)$$

where:

$$\mathbf{D} = \frac{1}{r^5}\begin{pmatrix} 3x^2 - r^2 & 3xy & 3xz \\ 3xy & 3y^2 - r^2 & 3yz \\ 3xz & 3yz & 3z^2 - r^2 \end{pmatrix} \qquad (1a)$$

and x, y and z represent the vector components of the distance from the dipole source to the field measurement point. $r = \sqrt{x^2 + y^2 + z^2}$.

Equation 1a may be extended for any number of field points, *n*:

$$\begin{pmatrix} \mathbf{B}_1 \\ \mathbf{B}_2 \\ \vdots \\ \mathbf{B}_n \end{pmatrix} = \begin{pmatrix} \mathbf{D}_1 \\ \mathbf{D}_2 \\ \vdots \\ \mathbf{D}_n \end{pmatrix}.\mathbf{M} \qquad (2)$$

and any number of magnetic dipoles, *m*:

$$\begin{pmatrix} \mathbf{B}_1 \\ \mathbf{B}_2 \\ \vdots \\ \mathbf{B}_n \end{pmatrix} = \begin{pmatrix} \mathbf{D}_{11} & \mathbf{D}_{12} & \cdots & \mathbf{D}_{1m} \\ \mathbf{D}_{21} & \mathbf{D}_{22} & \cdots & \mathbf{D}_{m2} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{D}_{n1} & \mathbf{D}_{n2} & \cdots & \mathbf{D}_{nm} \end{pmatrix}.\begin{pmatrix} \mathbf{M}_1 \\ \mathbf{M}_2 \\ \vdots \\ \mathbf{M}_m \end{pmatrix} \qquad (3)$$

or:

$$\mathrm{B} = \mathrm{E.M} \qquad (3a)$$

While this makes it possible to represent a source of any complexity, it is necessary to find a magnetic source distribution corresponding to a measurement from a degaussing range. For this a least squares fit is used to solve the inverse of equation 3a:

$$\mathrm{M} = \left(\mathrm{E}'.\mathrm{E}\right)^{-1}.\mathrm{E}'.\mathrm{B}\,. \qquad (4)$$

In practice, this solution is unsatisfactory because it produces values of M which, while they satisfy the equation, do not provide a good physical representation of the distribution of the vessel. A mathematical technique for forcing the magnetisation to be physically more realistic is given in reference (1) and will not be discussed further here.

Equations 1 to 4 form the basis of the magnetic modelling which is used in the UK magnetic ranges having been installed approximately five years ago. As noted above, anomalous results have been observed which have been attributed to CRM fields. To determine a source moment from which the CRM field can be calculated, an electric current dipole distribution has to be found by analogous methods to the magnetic solution above.

If we neglect the seabed and the sea surface, the equation for the current density field, $\mathbf{J}$, from an electric current dipole has exactly the same form as the equation for the magnetic field:

$$\mathbf{J} = \frac{1}{4\pi}\mathbf{D}.\mathbf{P} \qquad (5)$$

where $\mathbf{D}$ is as defined in equation 1a and $\mathbf{P}$ is the dipole current moment. The difficulty in adding vector electric field measurement to a magnetic range has been discussed above. Measuring the

electric potential provides an alternative that leads to lighter, cheaper sensors which have only a single additional electrode.

If we replace the current density, $\mathbf{J}$, in equation 5 by $\sigma\mathbf{E}$ where σ is the seawater conductivity and $\mathbf{E}$ is the electric field and note that the electric field can be written as the gradient of an electric potential, we can write:

$$\frac{1}{4\pi\sigma}\mathbf{D}.\mathbf{P} = \mathbf{E} = -\nabla V. \tag{6}$$

Integrating equation 6 gives:

$$\frac{1}{4\pi\sigma}\int\mathbf{D}.\mathbf{P} = -V. \tag{7}$$

We can define a vector $\mathbf{Q} = \frac{1}{4\pi\sigma}\int\mathbf{D}$ so equation 7 becomes:

$$\mathbf{Q}.\mathbf{P} = -V. \tag{7a}$$

The potential, V, is not measurable but the potential difference is measurable, so for five sensors we can write:

$$\begin{aligned}(\mathbf{Q}_1 - \mathbf{Q}_2).\mathbf{P} &= (V_2 - V_1)\\(\mathbf{Q}_2 - \mathbf{Q}_3).\mathbf{P} &= (V_3 - V_2)\\(\mathbf{Q}_3 - \mathbf{Q}_4).\mathbf{P} &= (V_4 - V_3)\\(\mathbf{Q}_4 - \mathbf{Q}_5).\mathbf{P} &= (V_5 - V_4)\end{aligned} \tag{8}$$

where $\mathbf{Q}_1$ represents the vector for sensor 1 and $V_2 - V_1$ represents the potential difference between sensors 1 and 2. This can be extended to include many measurement points) and many dipoles (as in equations 2 and 3 above) to represent an electric polarisation distribution) and then solved to find the polarisation by least squares fit as shown above (equation 4).

Following the analogy between electric field and magnetic field, the electric field is found from the polarisation distribution:

$$\mathbf{E} = \frac{1}{4\pi\sigma}\mathbf{D}.\mathbf{P} \tag{6}$$

We need to find the CRM field and that is given by:

$$\mathbf{B}_{CRM} = \frac{\mu_0}{4\pi r^3}\begin{pmatrix}0 & z & -y\\ -z & 0 & x\\ y & -x & 0\end{pmatrix}.\mathbf{P} \tag{9}$$

(Note that the equations given for electric current density, electric field and the CRM field are all simplified here assuming a sea with no boundaries. In practice, of course, the sea is bounded by its surface and the seabed. Above the sea surface is air which has zero conductivity. The seabed generally has a finite conductivity but one which is much smaller than that of the sea. The layers are accommodated by introducing a number of images of the source dipoles into the basic equations.)

Comparison of equations 1a and 9 reveals that the ferromagnetic field, $\mathbf{B}$, from a magnetic dipole decreases as $\frac{1}{r^3}$ whereas the CRM field, $\mathbf{B}_{CRM}$ decreases as $\frac{1}{r^2}$. Although the CRM field is much smaller than the ferromagnetic field at typical degaussing range measurement distances, it becomes relatively bigger as distance increases.

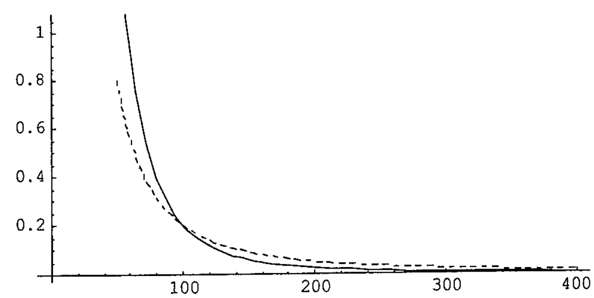

Figure 2 Comparison between ferromagnetic field (solid line) and CRM field (dashed line) with distance

Figure 2 shows the comparison between the ferromagnetic field and the CRM field with distance. In this example (using untypical distances and fields so it is unclassified) the CRM field becomes equal to the ferromagnetic field 100m from the source yet, at 25m from the source, the ferromagnetic field was five times the magnitude of the CRM field.

Although corrosion currents cannot penetrate the air (since it has zero electrical conductivity) they extend for large distances in the sea so the magnetic field from them extends into the air.

<u>Airborne Detection (MAD)</u>

Some aircraft are equipped with sensitive magnetometers (usually in a tail boom or deployed on a wire) with which submerged submarines may be detected. As the technology was first developed

for geological surveying for Magnetic Anomaly Detection (MAD), the technique of detecting vessels from the air is commonly referred to as MAD. The magnetic field from a distant submarine is much smaller than the Earth's magnetic field and, indeed, smaller than the fields resulting from the interaction of the Earth's magnetic field with the aircraft. Compensation of the airborne magnetometer for motion of the aircraft is thus necessary.

Hitherto, a vessel's magnetic field has been referred to as a vector field. Measurement of the components of a vector field requires can only be made in the co-ordinate frame of the measurement platform. If the measurement platform has any rotational motion, the Earth's magnetic field will be measured as rotating in the opposite direction. As flying aircraft always have some rotational moment (for example rolling and yawing) an apparent rotating field is always measured. The apparent rotating field is much larger the field measured from a submarine at a distance, so compensation for it is not currently possible. Therefore, it is customary to measure a property of the field which is rotationally invariant. For a vector field, the magnitude ($\sqrt{B_x^2 + B_y^2 + B_z^2}$) is invariant with rotation so MAD sensors effectively measure the scalar field. To determine the MAD threat to a vessel, the degaussing range software has to calculate the field which may be detected by an airborne sensor. It may be thought that it is simply necessary to calculate the magnitude of the predicted magnetic field at an appropriate distance. The following discussion will show why this is not the case.

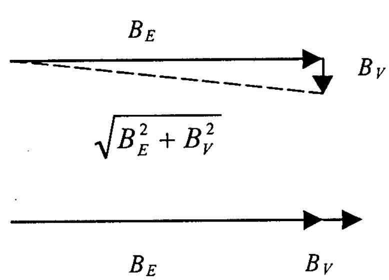

Figure 3 Vessel's field normal to Earth's field (upper) and parallel to Earth's field (lower figure)

Figure 3 illustrates the problem. The upper diagram shows the case where the vessel's field happens to be at right angles to the Earth's field. The resultant magnitude is given by $\sqrt{B_E^2 + B_V^2}$ (the dashed line in the figure). If B_V is very much less than B_E then $\sqrt{B_E^2 + B_V^2} \approx B_E$. For example, it the vessel's field is 10nT and the Earth's field is 50,000nT (nanotesla), $\sqrt{B_E^2 + B_V^2}$ is $\sqrt{50000^2 + 10^2} = 50000.001$ nT. The sensor would need a resolution of 0.001nT to detect a 10nT field. In the lower diagram, where the two vectors are parallel, their sum is simply the sum of their magnitudes: $50000 + 10 = 50010$ nT. (Note that the values for a vessel's MAD field given here are not representative of any particular vessel but are chosen to illustrate the problem and to be unclassified.) Effectively, the scalar sensor on a moving platform in the Earth's magnetic field detects only that component of the vessel's signature parallel to the Earth's field.

In air, the vessel's magnetic field consists of the sum of the ferromagnetic field and the CRM field but the only part of this detectable, B_{DET}, is the component parallel to the Earth's magnetic field. This is given by the scalar or dot product of the two vectors:

$$B_{DET} = \mathbf{B}_E . (\mathbf{B}_{FERRO} + \mathbf{B}_{CRM}) \qquad (10)$$

The measured magnetic field consists of the ferromagnetic field plus the CRM field, so accurate modelling of the ferromagnetic field requires removal of the CRM field from the measurement. While the CRM field is generally smaller than the ferromagnetic field at typical degaussing range distances, it is, for many vessels, by no means negligible. Therefore, the CRM field at the measurement sensor positions is calculated from the electric potential measurements, subtracted from the magnetic measurements, and the ferromagnetic model calculated from the result. This ensures that electric and magnetic source models of sufficient accuracy exist for the predictions described abovr to be valid.

UK Multi-influence range description

The UK multi-influence ranges, whether in the fixed or transportable configuration, consist of five underwater sensors from Ultra (designated MUWS10 and MUWS10A, depending on whether an acoustic sensor is fitted). The original magnetic ranges used Ultra's MUWS3 and MUWS3P which had serial digital communications with the shore. At the present, about seventy of these are still in use around the UK. The MUWS10 design reverted to analogue communication because the potential differences between *pairs* of sensors has to be measured by differential amplifiers in an underwater junction box. Furthermore, the sensitivity of the potential difference inputs is of the order of 5nV so digital signals within the sensor were not desirable to avoid electromagnetic compatibility (EMC) problems.

The underwater junction box (UJB) is quite complicated. It receives analogue signals from five underwater sensors and divides the magnetic and potential sensor outputs into two frequency bands – 0 to 5Hhz and 5Hz to 3kHz. Each band has analogue low-pass filtering to ensure out of band signals do not cause aliasing. As each sensor produces three static magnetic outputs, one pressure and one electric potential plus three alternating magnetic and one alternating potential, nine inputs per sensor are required at the UJB – a total of 45 inputs. Three complete channels are provided for future enhancement.

Following the analogue data acquisition and signal conditioning channels, the static data digitised by 24 bit A to D converters and the alternating data by 16 bit a to D converters. All the digital data is buffered before being packaged onto a serial data stream and transmitted to the shore using an ADSL modem. This has been designed to enable the use of the existing underwater cables – future enhancements include conversion to fibre-optic cables.

On the shore, data is archived to a networked 72Gbyte hard disk drive from which separate data processing computers for static fields, alternating fields and acoustic data receive their information.

An underwater junction box is shown on its glass reinforced plastic mounting in figure 5 just prior to deployment. It is approximately 0.5m in diameter and 0.5m long and weighs approximately 70kg in air.

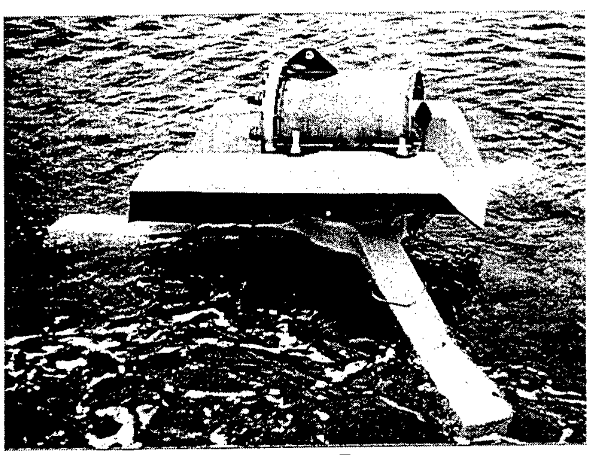

Figure 5 Underwater Junction Box

The UJB housing is titanium to minimise corrosion (which would also compromise the integrity of the underwater electric potential measurements) and to maximise heat transfer from the internal electronics to the sea.

Data Analysis

The static field data analysis is by display of the vector field compensated for water-depth and sensor position variations. The CRM, ferromagnetic and electric fields can each be displayed for the operator to assess the threat. Typical displays are shown in figures 6, 7 an 8 for illustrative purposes only since it is difficult to interpret these in monochrome.

In these figures, the left hand panel shows the signature along the vessel over two vessel-lengths, with the bow to the left and the right hand panel the athwartships cross section over three vessel-widths with port to the left. The three curves on each display indicate longitudinal, athwartships and vertical field components which are signified on the computer displays by different colours which cannot be seen here.

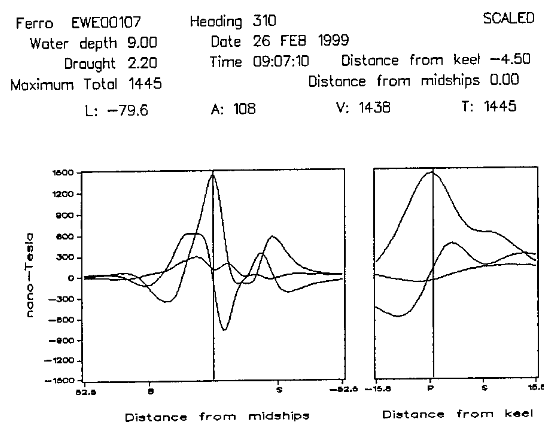

Figure 6 A ferromagnetic signature

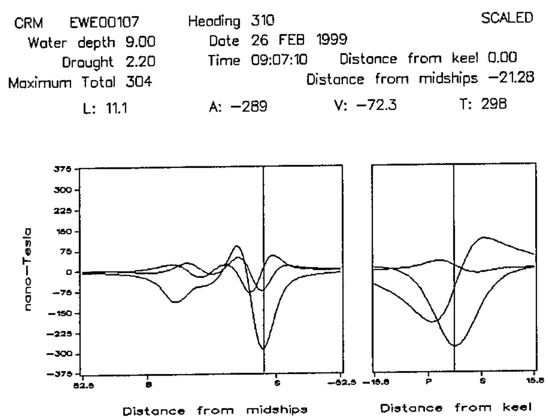

Figure 7 The CRM signature

Figures 6, 7 and 8 are for actual vessels but they have been scaled to make them unclassified. The scale factor is constant, so it is clear from comparison of figures 6 and 7 that the CRM signature is approximately 25% of the ferromagnetic signature – by no means negligible. It is also evident that the CRM signature is concentrated near the stern of the vessel as would be expected since the corrosion currents are concentrated around the propulsor.

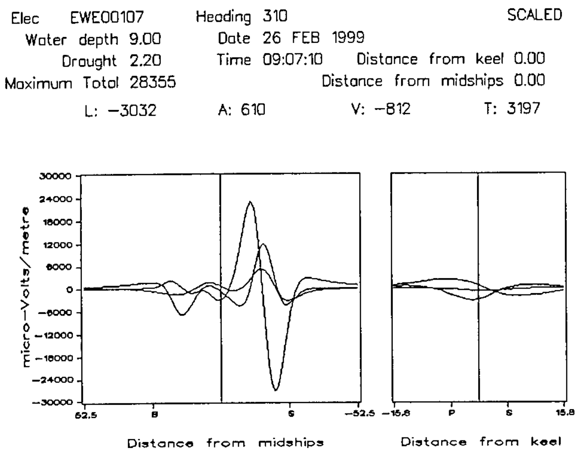

Figure 8 The electric signature

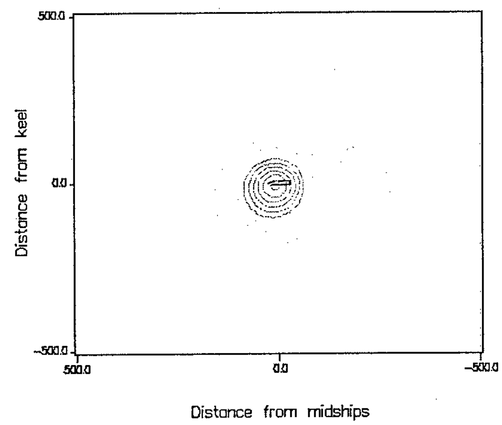

Figure 10 The MAD signature due to the ferromagnetic field only

As the electric signature and the CRM signature are interdependent, it is not surprising that both show a maximum around the stern of the vessel.

Figures 9, 10 and 11 show the calculated in-air signatures corresponding to the underwater signatures shown in figures 6, 7 and 8.

Figure 10 shows the MAD signature due solely to ferromagnetic sources. This is unmeasurable and can only be produced by calculation. The difference between figures 9 and 10 is obvious.

Finally, figure 11 show the MAD signature due to CRM. This is also unmeasurable and can only be produced by computation.

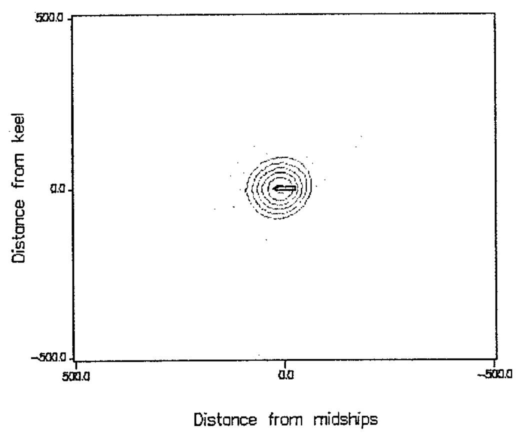

Figure 9 MAD signature due to ferromagnetic and CRM fields

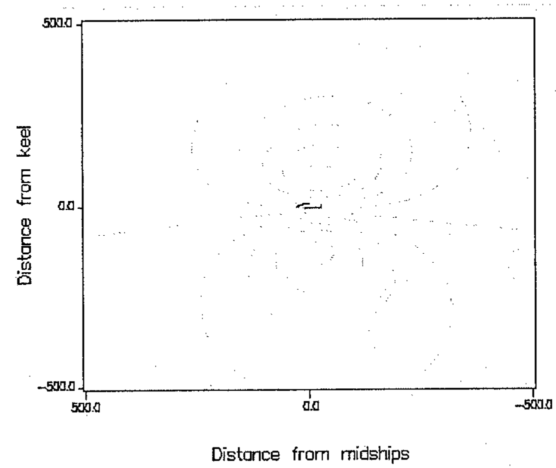

Figure 11 The MAD CRM signature

Figure 9 shows the MAD signature due to ferromagnetic and the CRM field. This is the field which would be detected by a MAD sensor with a sensitivity (after compensation for the aircraft motion) of 1nT. This is shown 150m above the vessel and for a 1km square centred on the vessel. Where the signature is detectable, the contour lines are shown in dark grey – light grey lines show an undetectable signature. (As with the other displays, the height, signature and threshold of detection are not representative of actual vessels but are shown for illustrative purposes only so the data is unclassified.)

The CRM signature alone from this vessel is not detectable with a 1nT sensitivity but the effect of the CRM signature in modifying the gross signature is obvious from the differences between figures 9 and 10.

Validation of results

Validation of the accuracy of the determination of the CRM field for actual vessels is virtually impossible due to the large ferromagnetic field which is practically always present. Fortunately, a trial took place a few years ago where a mine countermeasures vessel, with a very low

ferromagnetic signature, was ranged at 30m depth passing over both an electric field sensor and a range with five electric potential sensors. As described above, the CRM field was calculated from the electric model derived from the potential measurement and then compared with the measured magnetic measurement. The result is shown in figure 12.

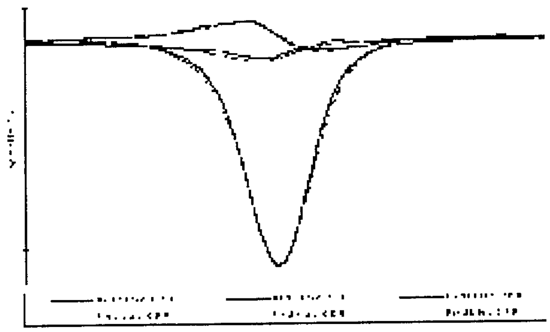

Figure 2 CRM field predicted from electric potential measurements compared with measured CRM field

The close agreement between each of the three axes is clearly seen. Close examination of the figure shows that one of each axis is noisier than the other – that is the measured CRM as it has the Earth's background noise present whereas the predicted CRM does not.

ELFE

The ELFE analysis and displays are not formalised at the present time. When these are implemented, the results will form the contents of another paper if their security classification allows.

Summary

The upgrade of the UK degaussing ranges from magnetic measurement only to multi-influence electromagnetic measurement has been described. Signatures have been shown for illustrative purposes only but it is clear from these that the corrosion related magnetic field cannot be ignored for threat evaluation – whether underwater or from airborne detection (MAD).

References

1 Webb, G J, Magnetisation Modelling Techniques, Royal Institution of Naval Architects International Conference "Warship '94"

Naval Combat Systems Integration and Testing – Today and Tomorrow

Dr T Crowfoot, C Cooper and A Froud, Defence Evaluation & Research Agency, UK

NAVAL COMBAT SYSTEMS INTEGRATION AND TESTING – TODAY AND TOMORROW

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Abstract

The Land-Based Test Site facilities at DERA Portsdown, are used for the integration, proving and acceptance of the Combat Suite for the Navy's Type 42 Destroyer, Aircraft Carrier, MCMVs and Type 23 Frigates. The facility combines real combat system elements, sensors, C3 and weapons, with a range of simulators and stimulators, which include the ability to create complex real time scenarios. Integration of hardware and software combat system elements, which have to work robustly in a real time environment, is notoriously difficult and the facilities have been shown to have saved its' costs many times over in the last 20 years.

Technology is moving on and the next generation of Shore Integration Facilities is likely to be more distributed, with combat system elements on separated sites, connected by high capacity networks. Future systems will be even more complex and the integration and proving issues are extending from Platform, to Force, to Joint Service interoperability. DERA is developing the Land Based Test Site into a unit that can help to solve these problems. The goal is for it to become the National Maritime Reference Centre, with high speed links to other such test centres e.g. the Land Reference Centre at Blandford and other DERA, military and contractor sites, and to have the necessary networked simulator/stimulator facilities to create the complex "virtual world" needed to exercise and prove such systems.

1.Introduction

1.1 Overview.

Portsdown Hill is a chalk escarpment 120 metres high. It has an excellent vantage point with spectacular views across the sea to the Isle of Wight. However it is much more than just a view.

Portsdown Hill has an interesting military history, as well as being an important area for wildlife, there is much more to explore. Combat System Integration takes place at DERA Land-Based Test Site. This paper describes the facilities at the Land-Based Test Site (LBTS) Portsdown, which are used for integration, proving and acceptance of the Combat Suite for the Royal Navy's Type 42 Destroyer, Aircraft Carrier, and the Type 23 Frigate. The paper gives examples of typical integration, testing and acceptance problems and how they have been addressed.

The paper discusses the latest plans for the next generation of Shore Integration Facilities (SIF), for future platforms such as the Type 45 Destroyer. We discuss the vision for the Land-Based Test Site, for it to become the National Maritime Reference Centre, and how this will be achieved.

1.2 Background

The difficulty of integrating Combat System equipments on modern warships has been recognised for some considerable time. Jordan Lee and Cawsey in their 'Learning From Experience report'[i] on the issues of integrating Software Intensive Projects within Naval platforms and the good practise in the use of Shore facilities quoted:- "There is already a facility at Portsdown – in effect a concrete ship – in which system integration can be demonstrated and tested. These facilities provide improved opportunities for difficult issues of system integration in platform projects to be addressed early."

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[i] Arrangements for Managing Major projects in MoD(PE)/1987

The Staff Requirement (SR) for the Type 23 Frigate includes the requirement for the Type 23 SIF. The Type 23 Shore Integration Facility was set-up at the Land-Based Test Site in accordance with the requirement, with the intention of providing a realistic, flexible test bed to enable the efficient development, linking, integration and proving of the Type 23 Combat System. The Type 23 SIF is the most comprehensive facility at the LBTS.
The primary functions of the Type 23 SIF are to trial and prove the interfaces between co-operating weapon systems, the proving of weapon and sensor operational software and the Human-Computer Interfaces (HCI). The SIF provides reproducible scenario environments tailored to engineering tests together with operational scenarios necessary for the integration and evaluation of the Combat System. Load testing can also be carried out under conditions of stress, which cannot be reproduced in peacetime exercises. In the longer term, the Type 23 SIF will provide a main site for post development support and testing and evaluation of the responsive adaptation programmes, thereby reducing the demand for time on operational ships.

1.3 Facilities - Design Philosophy

This section describes the range of equipments available to the users of the SIF, how they are connected together, and simulated and stimulated in a real time environment. The design philosophy for all our Shore Integration Facilities can be broken down as follows:-

- We fit as much of the real Combat System Equipments subsystems as possible. We don't have the guns, missiles and sonar transducers, but simulate these.
- We use operational software in all our systems.
- We stimulate subsystem equipments as near to the data or signal input source as practicable.
- We drive stimulators from a centralised Scenario Generator.

Combat System Equipment (CSE)

There is extensive range of CSE installed at the LBTS. The Type T23 SIF has the majority of the Combat System elements that you would find fitted on an operational ship. There are exceptions to this, there would be no benefit fitting sonar arrays, and so only inboard equipment is installed at the LBTS. The Command System for the Type 23 Frigate, (DNA) is linked to the other elements of the Combat System via a Combat System Highway (CSH). Two complete Combat System Highways are installed at the SIF. These are poll and response highways based on the DEF STAN 0019, giving a high level of service and redundancy. Triplicated highways are implemented with access via active remote highway couplers and spur cables, to each CSE. Each highway has two Highway Controllers Health Monitors (HCHM) which control member system polling and health monitoring facilities. There are still a few legacy equipments fitted that use point to point interfaces, and therefore are not connected to the CSH.

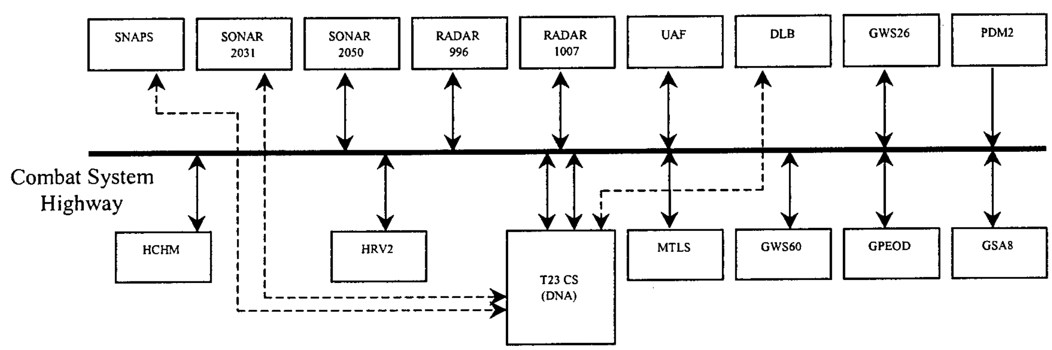

Figure 1 Typical CSH Configuration

Figure 1 shows the typical configuration of a Type 23 Combat System Highway.

The Type 42 SIF was installed when there was a different philosophy to integration, and also severe cost constraints. Most of the real CSE installed on Type 42 Destroyers have been emulated at the SIF. Again exceptions can be found, radars are fitted, and the T996 Radar can be shared with the T23 SIF. The Type 42 long range surveillance radar, and the Sea Dart tracker, are fitted at the LBTS, and are now the reference equipment for those projects.
The LBTS also has a number of data link networks. This enables users to configure systems so that different platforms can be integrated. Land lines enable a wide area network to be configured, so a ship in port can be included in a scenario run from the LBTS. The configurable system gives users the facility to run trials, with different platforms, on the same site.

Simulation Equipment

There is continuing debate regarding the use of simulation for integration purposes as against stimulation of real equipment when implementing a SIF. As mentioned, before the T23 SIF is based on stimulating real equipment, as opposed to the T42 where simulation is used. Both, however, have the capability of running a scenario in real time. The Scenario Generators (SGs) are capable of modelling hundreds of platforms, all manoeuvring. The playing areas are in excess of 8000Km square, and 32000m height and depth. There are many parameters that can be modelled, such as environmental conditions, e.g. wind, tide, sea state, clouds, and acoustic conditions e.g. sea depth, bottom type, shadow and zones. Emitters such as, radars, jammers, and sonars, can be attached to the platforms. The SGs are driven from a script, which gives the ability to loop the scenario giving an infinite run time. To enable feedback into the scenario, information on weapon deployment is sent to the SGs. The SG can then remove a hit platform from the scenario if required.

Within the T23 SIF there are two Scenario Generator Highways. These are based on the same principle as the CSH's except they are dual redundant only. Stimulators are connected to these in the same manner as real equipment.

Stimulators are designed in a manner to interface with the real equipment, as close to the first digital point in the system processing chain as practical. This maximises the stimulation of the real equipment hence giving a more realistic integration facility.

Recording and Analysis Equipment

The LBTS has an extensive range of recording and analysis equipment. There are several key systems in this area. Data And Event Logging System (DAELOS), is connected in a manner, so recording of all broadcast messages from both CSH & SGH are recorded, and time stamped. This gives the user the ability to cross reference events from SGH to CSH. DAELOS is configured so that unlimited recording is available, provided periodic back-up's are carried out.

If required the data can be transferred, filtered and then converted in to a format, (s record), which a DERA designed analysis tool can then use. Data Analysis System for Highways (DASH), gives the user the ability to look at one particular message in easy to comprehend graphical and tabular forms.
Data manipulation and display facilities are provided to suit particular requirements of individual messages. Without these tools integration of Combat Systems would not be practicable. These tools are essential to support of Combat System Integration.

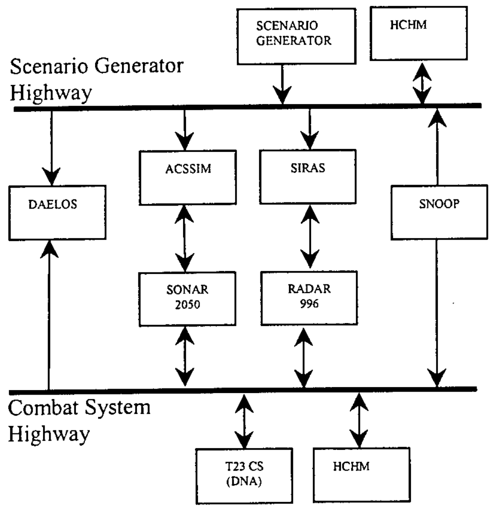

Figure 2. Typical SGH Configuration

Figure 2, shows part of the configuration of the SIF. The Scenario Generator broadcasts track and ship navigation information to simulators/stimulators, via the SGH. This is then passed to the real CSE equipment, which is linked to the CSH. Whist this is happening HCHMs are monitoring/controlling highway messages. DAELOS is connected to both, to record all messages.

1.4 Integration Testing and Acceptance Philosophy

This process is briefly explained by the following.

Once the equipment has passed the Factory Acceptance Trial (FAT), it would then be installed at the SIF. An installation inspection would then be carried out based on documents, produced for ship fitting. The Royal Navy's Captain Weapon Trials Authority (CWTA) would then inspect the installation. If any installation problems were found these would be passed back to the CSE project to correct before the equipment is fitted on a ship , thus saving valuable ship time. After this stand alone functional tests would be carried out. The next key step would be for the equipment to under go linking trials. This process is mandatory for all systems connected to the CSH. The CSH simulator gives the Combat System Engineers the ability to check that the equipment is operating in accordance with the highway protocol and will not corrupt other messages on the highway. Once the member system has gained the necessary certification, it is then permitted to connect to the CSH for full scale system integration to commence.

2. Problems that Typical Combat System Integration have highlighted

In line with smart procurement these large software intensive projects are procured by an incremental acquisition approach, i.e. the software is developed in a number of phases, taking maybe 4-6 phases to complete the build. On average we expect approximately 1000 pick up items on each phase. These items range from software faults, incorrect specifications and Combat System design problems.
Below are examples of anomalies found. Some of which would have had catastrophic consequences if not corrected.

1) Potentially threatening, fast, inbound targets are uniquely identified with a track number. This track would then be passed to the Command System, which would then carry out Threat Evaluation Weapon Assignment (TEWA). In this instance the operator confirmed the track as "Friendly". The aircraft was then tracked outbound from the ship. It then turned inbound for a second run where it should have maintained the "Friendly" identification - but didn't. It was re-allocated as "Hostile". The air defence weapon system then carried out a simulated engagement , much to everyone's surprise. A solution was identified and implemented within a new issue of software.

A further trial was arranged and the SIF was again used to repeat the trial and confirmed that the software modification now ensured that friendly tracks would not be engaged by the weapon system.

2) A recent build of Command System software, was found to have a problem displaying tracks on to the Multi-function console (MFC). It was found there was a difference of up to a minute between tracks being displayed on the planned

position indicators (PPI) displays, and the MFCs. The consequence of this was that operators actions and command decision were not effective. This could have meant a missile might have hit the ship before the operator had time to respond with counter measures. Following a software modification and retrial at the SIF this fault has been rectified.

3) Command Systems often under go contractual reliability trials at the SIFs. These trials stress the Combat System under high load scenarios for long periods of time. It would be impossible to achieve such a comprehensive trial onboard ship.

As an aside, it is worth noting the approximate amount of source code contained within Naval Command Systems. Table 1[ii] shows the number of faults per lines of code you would expect to find in a typical software project. You can see from the table the number of faults found for both small and large systems. . A ship is a large software system which is why progressive software developing and testing at a SIF is so important if reliable systems are to be delivered to the Fleet.

Pre code Generation	Fault Density* (per 1000 lines of code)		Estimated faults	
	Low	High	Low	High
670,000			670	5628
	1.0	8.4		
1,770,000			1770	14,868

*Fault density depend on

- Complexity of code
- Skill of company
- Size of product
- Novelty of product

Table 1 Software faults.

3 Learning From Experience

Over the years we have learnt a lot from Integration of different Command Systems and the way the SIF operates. We have seen the simulation and stimulation philosophy change as the requirements for integration and testing evolve. Users are now demanding more functionality, reliability, capability and interoperability. This section lists some of the lessons learnt.

- Incorporation of real equipment is essential for system integration. Use of equipment simulation is limited to integration de-risking and operator training. However if stimulation of real equipment is used this can be real time and repeatable.
- The life of a SIF will be longer than that of its components, so obsolescence will always be a problem. The use of Commercial Off The Shelf (COTS) hardware and software does not always provide a solution and brings its own unique problems.
- Standardise hardware as far as possible and ensure software is written with long-term support in mind, (e.g. no clever system calls, which will not work with the next version of operating system.)
- The ability to record all data for the duration of the longest scenario run required is essential. Choice of recording medium is important because of the large amount of data that needs to be recorded.
- The essential analysis function is rapid selection of large amounts (gigabytes) of recorded data with comprehensive filtering criteria.
- Users should be able to set up their own ad-hoc analysis procedures by selecting and combining a set of basic operations since it has proved very difficult to predict what they will need to do when evaluating system anomalies.

4 Future Platforms

DERA have research programmes in support of many future platforms which include, the Future Aircraft Carrier (CVF), the Future Surface Combatant (FSC), the Future Attack Submarine (FASM) and the Type 45 Destroyer.

The Type 45 Anti Air Warfare (AAW) Destroyer is required to give the UK's Royal Navy a destroyer with specialist AAW capability. It will replace the capability of the Type 42 Destroyer, a platform which is now suffering from obsolescence and is costly to maintain.

[ii] Software faults table. IIE publication.

DERA have been involved with research programmes supporting the Type 45 Destroyer and believe they could contribute to it's integration with the Principal Anti-Air Missile System (PAAMS), and the Multi-Function Radar (MFR) SAMPSON. DERA are currently in negotiation with the Type 45 and PAAMS projects on the possibilities of installing a test and integration facility at DERA Fraser, an over water range located on the shore of the Solent. The location is representative of the environment that sensors would be expected to operate under. A secure data link to the LBTS would provide integrated sensor and Combat System Integration facilities.

5 What next? New Generation Shore Integration Facilities.

With new technology being developed at an alarming rate the way SIFs are designed must change. The new generation of Shore Integration Facilities will have to be adaptable not only to new technology but be responsive to change at short notice although long term support to many platforms will still be required. With partnerships with industry and other countries ever increasing we need to look at networking to other integration and reference sites in the UK and overseas.

5.1 Networks

Future naval combat systems will demand more from the Combat System Local Area Networks (LANs). Where the current LAN was only designed to handle tactical real time data it is likely that in the future the highway will need to support other services like audio and video. This requires increasingly large amounts of bandwidth from the networking medium.

DERA the team leader of the Combat System Integration (CSI) programme, (which is a five-year UK Ministry of Defence research programme, integrated with the Defence Procurement Agency (DPA) and UK industry) has many areas of research, one of which is High Capacity Networks.

There are currently several avenues of research into LANs and Wide Area Networks (WANs). These are being looked at for a possible replacement CSH and for connection of different integration sites.

DERA has also been supporting industry in trials with legacy systems, integrating them with Fibre Optic technologies.

The likely COTS basis of future Combat Systems, and particularly the likely use of 'Middleware' between the applications and the networking technology, has moved the emphasis away from full military networks towards the use of COTS networks, or at the very least, the use of standard operating system network drivers.

The emerging Gigabit Ethernet switched LAN technology is part of the CSI research programme along with ATM (Asynchronous Transfer Mode). It is anticipated that the Gigabit Ethernet will support the data rates and bandwidths that a future platform will require.

5.2 Future Systems – Interoperability

We are now looking at more than just integration of a system on a platform. Interoperability between different platforms at force, joint, and coalition level is required. DERA is currently working on research programmes to bring together equipments in to the same virtual battlespace to aid future interoperability studies.

Currently DERA LBTS have a DIS/HLA gateway fitted, which enables data link trials to use training equipment manufactured by a US Company, linked to the SIF, and via land lines to ships in port.

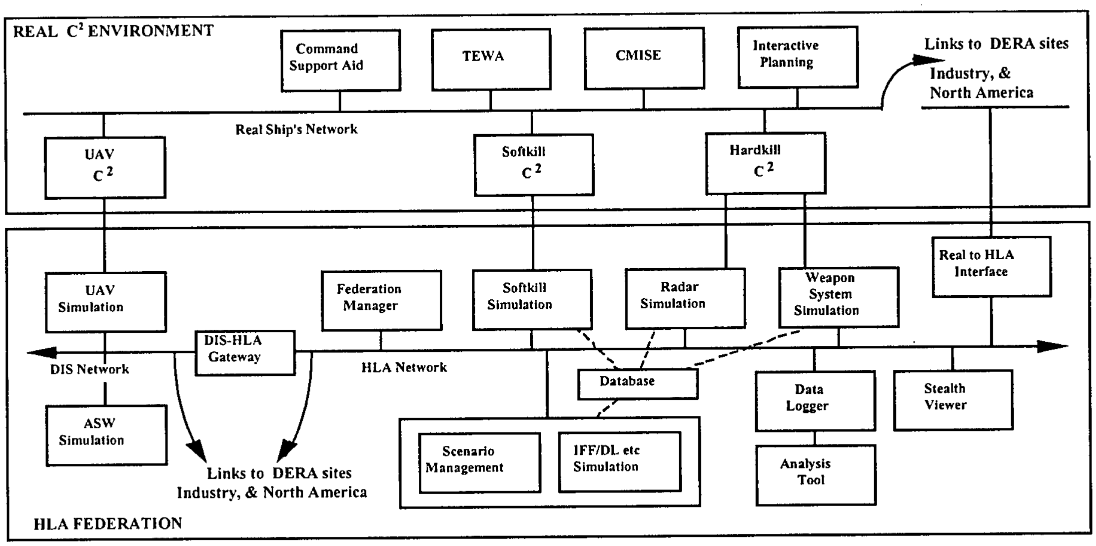

Figure 3 DERA CSI Testbed

The building of synthetic environments to meet both testing and training requirements has led to a number of standards being developed world wide to support the interoperability of simulation systems. Distributed Interactive Simulation (DIS), and the future development of a new standard High Level Architecture (HLA), are examples of architecture standards that are intended to facilitate interoperability between all levels of simulation. DERA have developed the CSI Testbed, Figure 3. This is a generic combat systems integration facility where many demonstration or real equipments can be integrated and tested in a comprehensive synthetic environment. It is being used to link to other such testbeds in the UK and US. It makes extensive use of both DIS and HLA standards for the simulators and stimulators.

6 The National Maritime Reference Centre

DERA have recently taken over ownership and operation of the Land-Based Test Site. DERA have already relocated the Combat System Integration (CSI) research team to the LBTS. This initial extension of capability at the LBTS will form the nucleus of a National Maritime Reference

The NMRC's purpose is to reduce risk at all stages of the acquisition and ownership process and be driven by a need to ensure that operational capability is maintained throughout a platform's life. Its aim is to be recognised as an authority for high level systems integration, performance evaluation, support and training. The NMRC should accommodate industry interests and initiatives which maybe offered as part of a shared approach as well as other DERA initiatives like the Virtual range.

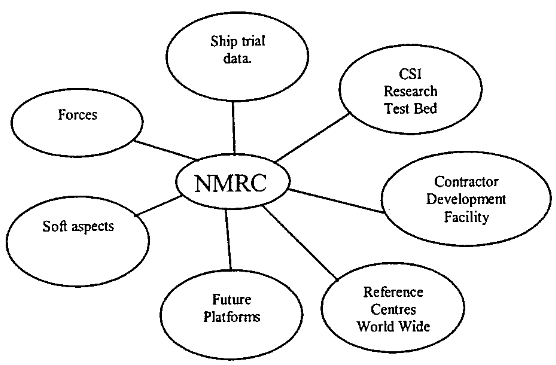

Figure 4 Wide Area Integration Facility

The virtual range concept would enable ships to carry out trials with more than just real threats from the range but would include virtual tracks. This would also test the system under a higher load and put the operators in a more realistic environment, making best use of the range.

To fully realise the NMRC requires an approach which satisfies the aspirations of stakeholders. Such an approach needs the support and active involvement of both MoD and industry, which in turn means it has to be pragmatic and cost effective. In turn this suggests the NMRC should be shared and focus on developing core skills and capabilities through the realisation of specific programmes in a incremental step by step manner. Links with other reference sites such as Land Reference Centre at Blandford, are envisaged, as well as the established links to US facilities.

7.A Final Thought

The facilities at Portsdown have now been a landmark on the Portsmouth sky line for some fourteen years and will continue to evolve. During this period the UK National Audit Office carried out a study in to the Type 23 Frigate Programme, this reported that potential savings for the Type 23 Project over a 25-30 year period based on records from activities at the SIF was in the order of 6 ship years.

Looking to the future, the site is evolving as a node of a global network of reference centres demonstrating platform, force, joint and coalition interoperability, of which this will be the National Maritime Reference Centre........

Back to Basics – Fundamental Consideration for the Systems Engineering and Related Test & Evaluation Problem Space

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BACK TO BASICS – FUNDAMENTAL CONSIDERATION FOR THE SYSTEMS ENGINEERING AND RELATED TEST & EVALUATION PROBLEM SPACE

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Abstract

This paper takes time out to consider the fundamentals involved in the engineering of large systems. It identifies weaknesses in the current systems engineering and test and evaluation practices. It begins with development of a pragmatic, model of the Systems Engineering problem space in which many design teams are interacting with the common goal of delivering a system on time, at least cost and to at least expected performance. This model is then used to reveal fundamental deficiencies of current methodologies showing that T&E and SE are essential partners in the whole life cycle problem. It also exposes where the serious barriers arise to more effective systems development.

Introductory Remarks

In all endeavours it is necessary to keep track of the fundamentals involved and to study their changes. This can reveal new insights in how to bring about improvements. This paper addresses the practices of Test and Evaluation (T&E), and its highly related Systems Engineering (SE), in the context of them supporting the whole of life design and operation of large complex systems.

For too long these two areas have been followed with less than adequate interaction. For example the T&E oversight activities of the US DoD Office of Secretary of Defense (OSD) had little representation of Systems Engineering until recent times; the International Association for Test and Evaluation (ITEA) conference content can be said to cover SE in context but presentations rarely address T&E practice in its relationship to that of SE. Even more surprisingly is the fact that the content of symposia and topics of the 37 Technical Committees of the International Council of Systems Engineering (INCOSE) give only scant attention to T&E. Leading SE text books also do not give adequate coverage to T&E. The most recent major statement of the knowledge of SE is Sage (1999). It has little of relevance about T&E and how it should be implemented as a risk reduction process in SE practice.

It is reasonable to assert that the prime drivers in current engineering of defence and aerospace systems seek:-

- Improved commercial gain
- Improved defence capability
- Improvement in all of the cost, time and performance factors
- National accountability and reputation

The key area of concern here is the process by which systems are engineered, this then largely deciding how T&E is best implemented. These two factors cannot be treated as independent issues.

The three main risk areas in SE are the 'CTP' factors

- T - time to completion (controlled purposefully by project management)
- C - cost to completion (controlled purposefully by accounting processes)

and, with these two met, the system also has

- P - whole of life technical performance needed (controlled, or should be, by purposeful and appropriate T&E)

To perform these three risk reduction strategies simultaneously requires they all be well integrated. T and C practices are but T&E is not, as will developed later.

Where would one look for the 'Best Practice' for this combination? In the 1960-70s defence and commercial systems were developed as though they are quite different worlds. Today they have come together but there is clear evidence that they are not fully the same and thus the two practices can only converge so far - and we appear to be near that limit today.

In defence systems the leadership in their engineering is arguably with the US defence contractor sector with the UK MoD having just picked up the leading features via the Smart Procurement Initiative.

In the commercial sector it the multi-national Level 1 systems houses that are leading the way.

Defence procurement is fast giving way to emulating, where it can, the commercial practices.

The last decade, especially, has seen major changes in SE practice, with T&E being pulled on to a mixed extent.

One would be forgiven for believing that some major new ideas have been implemented. However, analysis of what has been happening shows they have been a continuum of extrapolated method. The boldness to be noted is the extent to which systems houses have changed their practices through large cultural shifts and heavy facilities and support tools investments.

This brief overview has set the background for investigating where major improvements are needed.

Trends in Systems Engineering

Since the 1940's systems development has needed formalised processes to be able to manage its ever- increasing complexity. The US has generally taken the lead with standardisation of the SE process but other less well known practices have tracked this culture. All recognise the essential need for serial stages/phases - Concept, Realisation, Detailed Design, Manufacture, Operation, Disposal.

SE Process adoption began as a formalised expression with the Mil-Std 499 of 1969. This has become known as the Waterfall Process. Here the philosophy is that each phase is a self-contained activity for which output products are the material needed to feed the next phase. A good descriptor is that documents are 'Thrown over the Wall' to the next phase.

This process was predicated on the belief system that Customer Requirements could be set early, that they would be correct, that they could be reticulated ever on downward, and that the sum of the parts when put together would give the performance needed. It lacked enough feedback so workers went the way they saw was best with insufficient regard as to whether their contribution was 'right'. T&E was present as localised designer testing and milestone evaluations for payments. There was little emphasis on whole of project life T&E planning. Waterfall was too slow, too expensive and did not produce as well as expected. This was, however, a major step forward for the process was externalised, very well documented and today has given us a wealth of information on 'what to do' with some 'how to do' information on managing large SE processes.

From this base line process evolution has been taking place that leads us to where we are today. The first major step forward was to recognise that the link of events had two kinds of activity. First, paper studies. Second, manufacture of objects. (Early SE processes used in defence systems gave little attention to 'whole of life' issues.) These two could be folded into a Vee allowing strategic test and evaluation to be applied. This improvement allowed the various steps of the implemented design to be progressively tested against the breakdown requirement. The V diagram is used extensively today and is well documented. Its T&E is more efficient but it also lacks a sound forward-looking T&E plan that is able to give technical performance risk management guidance.

The UK MOD Downey cycle is an adaptation of these principles.

The demands for better 'Time, Cost, Performance' factors pulled on investigation of how to improve the SE process still further. In the 1980's academic and industrial research in manufacturing systems picked up on the notion of 'Concurrent Engineering' (CE). This is a simple philosophy. Can any activities of later phases be started before the phase preceding them is completed? Rather than wait for final design details can the next steps be started, even if some later adjustment is needed? This cuts down the time of the cycle and also better integrates the experiences of later phase activity. This may have been a bonus from CE research but it led to the integration of a representation of all facets right through whole of life. This implements the 'early error correction' philosophy wherein it is well established that early correction can yield significant overall savings. By 1990 the concept of Integrated Product and Process Development (IPPD) was in use in dominantly US industry. By 1992 such corporations as Boeing had implemented CE and IPPD in a major way, an early well-known product from this new culture and methodology being the Boeing 777 air plane.

Integrated Products Teams (IPTs); concurrent engineering; guidance SE process standards; process re-engineering; and computer supported SE processes are the 'Best Practice' of today.

So where to next? Can there be other philosophies for tuning the SE process?

There are indeed a number of variations that evolve the process still further but they tend to be special cases of the above. They are all used to a limited extent. They include incremental acquisition in which the first phases develop a basic design, enhancing the system performance

in later steps. (This is the process preferred in the UK MoD's Smart Procurement.) Another is continuous procurement in which improvements are added as small increments. Here resources are fed in to gradually build up capability as it can be afforded.

Taking the various SE processes to the limit of where they might be expected to evolve suggests the end point would be a small grained system in which concurrency is smoothly applied. This is explained later.

The latest major activity to pick up on these good features in national way is the Smart Procurement Initiative of the UK MoD. It takes on board the best of the above practices. It gives a great deal of flexibility to leadership to use these various philosophies.

But is the SE process well enough understood to tailor it? Are there aspects that can be improved in as powerful a manner as did CE and IPPD philosophies? This will be addressed below.

Here has been summarised 50 years of SE process development. An overview is now needed for T&E.

Trends in Test & Evaluation

All well managed projects have considerable test content in them. Requirements have tests associated with them. The high level 'purposeful' and the 'suitability' (R&M – Reliability and Maintenance - tends to be the term used in the UK MOD) statements define the system issues that are to be satisfied to meet the needs of the customer and users. These statements are the logical starting point for setting up tests that provide data to feed evaluations.

As a design develops the design team conducts localised tests to be sure the design meets the requirements that have flowed down to them by the requirements breakdown process.

This kind of evaluation is common practice and is often not stated as a formal process but one being conducted within the team's normal practices. This is appropriately called 'informal T&E'. The practitioners feel confident they know what to do - but usually cannot justify why they tested what they have. Their professionalism is thought to be sufficient basis for deciding T&E issues.

Despite all the good intentions there is much evidence to show that adding up the sum of reticulated requirements does not lead to a satisfactory system. A simple reason is that the lower parts too often are not interfaced to higher and other levels sufficiently well to know what the sub-system they are building is supposed to be able to do.

Around 1980 key US sponsors became tired of too many failed defence systems - the CTP factors were variously not met. A major study led to Congress passing laws requiring all major defence projects to have much improved T&E processes and that there be oversight by Pentagon government of programme performance. This led to the creation of the separate OSD offices for development and for operational T&E. Major initiatives included requirement for the Test and Evaluation Master Plan (TEMP), certification of T&E employees, standards for T&E practice, budgets for national T&E improvement programs and central coordination of many T&E services. The TEMP was primarily created for programs to give OSD staff oversight of crucial information needed to be able to monitor programme progress.

Political reasons appear to have separated development T&E oversight from that for operational T&E. The US Service arms continue to conduct their own test facilities and T&E processes in the manner that they choose. The TEMP is provided to the OSD as an early part of Program documentation.

In 1999 a US DoD national review recommended a much closer link between whole of life issues, SE practice and the OSD T&E agencies. Reorganisation recently took place to this effect but still with DT&E being a separate OSD activity to OT&E.

A TEMP recognises that informal T&E is essential and that a forward looking T&E plan is also needed that ties the data obtained from tests back to the Critical Issues (CIs) that are set into the Customer high level needs statements. This helps to ensure:-

- The right tests and evaluations are made
- Test requirements are planned
- Facilities are available when needed
- Test resources are used efficiently
- Test effort is traceable to the essential needs.

Today TEMP documents are relatively common-place in US defence programs – but seemingly because of legal requirements as much as any reason! They are not always used to good effect as it seems the virtues of such are not well recognised with T&E being allowed to fall back to the final 'see if it is to the need' situation.

TEMPs are not just used as a defence systems practice; some US industries use them.

For some years the Australian DoD has called for TEMPs as part of Defence Instructions re program management but still few are actually written. It appears that their risk control value is not appreciated.

In the UK some contracts to contractors have called for TEMPs but it has not been a common practice - as far as can be seen for contractors are not that forthcoming on how they conduct T&E within programs.

In recent times the various western defence acquisition agencies have recognised the lead possessed by the large aerospace and defence companies and are moving their cultures to make the best of that experience. Whilst there appear to be major gains to be had there are also clear reasons why the defence business appears to never be able to make use of all of their advantages.

This short overview also needs to include the impact of SE and T&E practices as used in other areas of large commercial practice. One dominant area is the telecommunications field. This has a total turnover much greater than defence spending; regards a $billion programme as a normal lead-in cost; works within very rigid interfacing protocols; implements comparatively small advances to a proven system; uses proven technology and has to upgrade their systems in a seamless manner over 24hrs a day, all year, all time. For all of this it also has huge commercial failures.

The car industry is also after major improvements in the CTP factors in order to stay competitive in an over supply situation. It makes, compared with defence needs, only small technical changes to its deliverables. Its product is very mature and there is little room to move in design. Its also works within a tightly standardised interfacing situation.

There are certainly things to learn from the civilian systems world. The US DoD has recently had a three person Military Fellows team study the situation. The major aerospace companies have interesting initiatives in place to further tune the CTP factors. Examples include the Boeing 'Create New Air Plane' initiative; the Lockheed 'Lean Air Craft' initiative; and the Jet Propulsion Laboratory 'Create New Products' initiative. There do not seem to exist counterpart programmes in the EU!

So why give this background? This paper now is in the position to explore future potential trends suggesting how and where SE and T&E will be able to still obtain major improvements in the chase for optimum CTP factors.

The preceding material lets us approach two main issues, one in SE and the other in T&E, where considerable improvement can still be obtained. These are now developed.

The Teaming Model of Systems Engineering

The general development of SE practice in Defence industries appears to concentrate on tuning of the SE process itself. The SE process standards started with heavy 'prescription' and have evolved now to be 'guidelines' that leave considerable flexibility of implementation up to the project manager and systems creator.

The latest trends are to apply 'model-based' thinking to the SE activity. This trend is relatively new in its acceptance for study. It is being interpreted to mean anything ranging from:-

- Convert the SE process guidelines from words into interacting block diagrams (first step in implementation of what the control systems discipline calls 'systems identification')

to

- Develop a formal mathematical model that can be executed in a computer to gain optimal performance (the later steps in systems identification)

Model based thinking is standard practice in engineering of those kinds of physical systems that succumb easily to formal 'hard' mathematical description.

To this end INCOSE has established a strongly supported Working Group for Model Based SE. It held a major session at its annual Symposium held in Brighton UK in June 1999.

It is logical to see this sort of development emerge for it is driven much by engineers who are steeped in the reductionist culture and have little time for the alternative phenomological way of thinking that is found in the humanities – where it is accepted that formal models of people systems are not feasible to any really useful extent.

Now presented is a simple 'show stopper' argument that sheds light on the futility of chasing model-based SE as the main thrust for gaining improvements of significant order.

Discourses in SE use the SE process as the foundation – define the process phases and then hang on that framework the knowledge relevant to the parts of that framework.

The human organizational issues involved are given low exposure in SE organizations. So let's start with a different foundational model being that the task of a SE activity is to integrate the contributions of hundreds of engineers to all seek to maximise the way they add value by enhancing a given or new system toward new levels of performance. This is here called the Pragmatic Teaming (PT) model.

Figure 1 shows the first stage of its development. The key features are:-

- Teams (small oval cells) exist to design a system that satisfies a Needs Statement giving the best performance for least cost and cycle time
- They ideally work together exchanging their existing and developing knowledge to move the whole design effort toward delivery of the required product in a continuous manner
- Below the overall planning and leadership level they work on tasks within their area of competency on the 'already knowing what to do' basis.
- All teams carry out much the same intellectual task – identified as the SEP (System Engineering Process)
- Interface studies (n^2 matrices/diagrams methods) show teams need to interface the knowledge of their cells with at least 50% of that of all other cells.
- Strategic grouping reduces the interfacing problem somewhat but still leaves a massive knowledge flow situation.

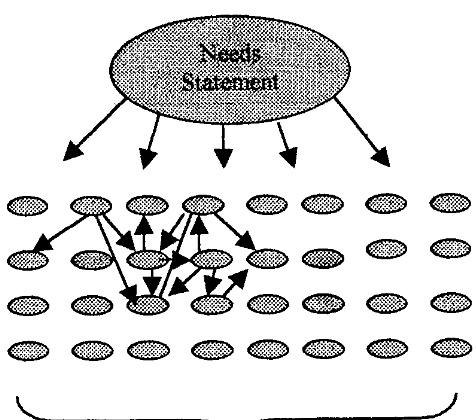

Figure 1. First Step toward Pragmatic Teaming Model

Overall this model (called the 'organismic' model in organisational science for the parts, the organs, are all doing their own thing) is not successful as it lacks overall guidance. It identifies well with the waterfall situation in which the cells carry out their work to the reticulated specifications with less than enough communication.

Pragmatics of how a system is developed are now used to further develop this first stage model by adding leadership to each of the teams. This allows communication of knowledge between teams and gives the whole overall leadership - the Systems Engineer function.

Fig 2 gives the pragmatic model as SE is generally practiced today. This model is known as the 'neuro-cybernetic' organisational model (or 'viable' model). It is well established in systems science and is not contentious as to representing the SE activity reasonably well.

With this simple model we can easily and soundly identify the problem that appears to this writer to be major showstopper to improvement in SE activity.

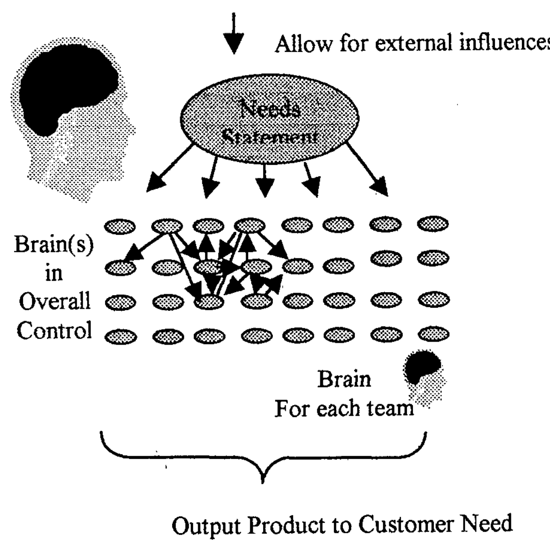

Figure 2. Pragmatic Model Able to Show Barrier to Progress

Let us recall that the mission of the design team system is to move the many teams involved toward the 'right' end result with the CTP factors as optimisation requirements.

The 'engineering science' methodology for finding the optimal solution to this kind of network problem is to treat this set of interacting teams as a topology calculation problem. The first step is to

set up descriptive equations for the behaviour within a team in terms of input/output relationships. Then are established the linkages between all blocks and the behaviour of those linkages as additional processing blocks. With this all done it is then feasible to set in initial conditions and relax the system toward its optimal state. Model-based systems engineering appears to be advancing according to this paradigm.

This methodology, however, will soon come upon a great barrier to its effective deployment.

If the flux within the network consisted as only mass or energy flows then descriptive analytical formal methods promise limited optimisation success - even for non-linear situations. However, the stuff flowing between cells is 'information' and 'knowledge' as well as 'hard data'.

At the current state of understanding we are nowhere as advanced with formal characterisation of human messaging as we are with formalised mathematical calculation of the properties of networks. Engineers have little understanding of the scholarship of human

communication - such as of 'semiotics' (the theory of messaging); Knowledge Based Systems and linguistics and grammatics; all being disciplines where we might find a foundation for treating knowledge flows within nodal networks of cooperating teams.

If we cannot reduce human communications to formal formulae representation then we are a long way from being able to optimise teams using 'engineering' control systems paradigms.

At present considerable effort is being placed in standardising the SE 'data link' between computers used by designers – such as by the SEDRES project and its developing standard. This writer suggests the data link aspect is a much lesser issue when compared with the need to adequately understand the human communication need. Both types of interfacing links must be well understood in order to make a significant impact on optimisation of SE activity.

We need considerably more research in place to investigate the human teaming optimisation model and its knowledge flows. There, however, exists only a handful of researchers in the world looking at this highly important aspect. One line of attack is 'Soft Systems' as constituted at present (originated by Checkland (1981) and extended by Flood and Jackson (1991)). Progress there is little more than past identifying the problem in organisational terms. For progress to be made engineers and scientists must cooperate more with organisational scientists, with cognitive psychologists and other humanities disciplines. The answers do not appear to lie in the scholarship or established practices of engineering!

In summary, SE process is the current emphasis of improvements to SE practice. However, by looking at a Pragmatic Teaming model of the SE activity it is easy to see and prove that a major hold-up to progress is lack of attention being given to the human communication-interfacing problem of knowledge, as well as data, within a teaming network. This is a vital area in need of greatly improved understanding in terms of computer network operations. Programmes such as the major SEDRES one may well improve the interfacing for data links between designers but the meaningful knowledge aspect will still remain - and it is tough research problem!

Attention has been given to the SE process - yet this is a T&E meeting. Why?

T&E is the process by which technical performance risk can be better controlled. Its effective application requires a deep appreciation of the system operation to which it is being applied. T&E practitioners rarely have experience in the SE aspect, and vice versa. This short summary might assist bridge that gap for they have not been adequately interfaced to date.

Let us now look into where T&E practice can be improved to assist optimise the CTP optimisation factors.

T&E Practice Based on Foundational Concepts

Implementation of T&E can be built up from sound scientific foundations. This has been recognised in the US DoD T&E process as defined in their TEMP guidelines and later teaching courses. That approach has been further developed by work at the Australian Centre for T&E (now part of the Systems Evaluation and Engineering Centre) and more recently in the teaching of the new MSc in Systems T&E at the University College London. Three key processes can be identified as essential to implementation of technical risk control. These are a use of a defined Systems Engineering process, a T&E process and many Measures Trees.

An adequate account of the nature and scope of SE processes used has already been given. Sound T&E cannot be applied unless the process is understood and documented.

The T&E process can be identified as the procedure for establishing new knowledge about

the performance of parts and the whole of a system design and operation activity. It has been well established that this is consistent with the steps of the well-accepted 'Scientific Process' used to gather new knowledge of a dynamically changing activity. Fig 3 shows a summary chart comparing the scientific process with the steps of the T&E process.

Scientific Method	T&E Process
I. Develop Hypothesis	
1. Identify Question/Problem	1. Develop Test Objectives
2. Formulate Hypothesis	2. Estimate Performance
II. Experiment	
3. Plan Experiment	3. Develop Test Method
4. Conduct the Experiment	4. Collect Test data
5. Analyse Results	5. Calculate MOPs
III. Verify Hypothesis	
6. Check Hypothesis	6. Compare with Thresholds
7. Refine Understanding	7. Retest or extrapolate

Fig 3 Chart comparing Scientific Processes and T&E (From SEEC (1998))

Sound adherence to the above steps of the T&E process leads to reliable and relevant knowledge gathering about the performance of a programme.

However, use of a sound SE process and T&E process is not sufficient.

It is not feasible to test and evaluate every part of a major program as it develops. The need for designers is to decide what are the critical high-level issues and set up the T&E Master Plan to ensure these are addressed and monitored as the programme progresses. This is not to say that T&E is not needed at the localised level but that an overlay T&E programme is needed that addresses the overall integration issues adequately.

For each Critical Issue (CI), identified from the high level capability requirements statements, there needs to be set up a breakdown of several kinds of Measure. This breakdown has to have a traceable hierarchy. Terminology used for the various measures is taken from US practices. Fig 4 shows the various measures in the generic measures tree (Some US DoD teachers call this a 'dendritic diagram' and draw the tree as a horizontal form.)

To establish the overall programme capability at any time the current value of all measures predicted to begin with are calculated according to the tree trace with weightings applied to each. This gives a current estimate of the top level need but cannot yield its level of uncertainty. This is obtained by assigning the best estimate of uncertainty to each measure at the time. With these in place it is then relatively straightforward to calculate the uncertainty of programme maturity at any time. These calculations can largely be automated using well-established consensus and statistical methods for carrying out many to one mappings.

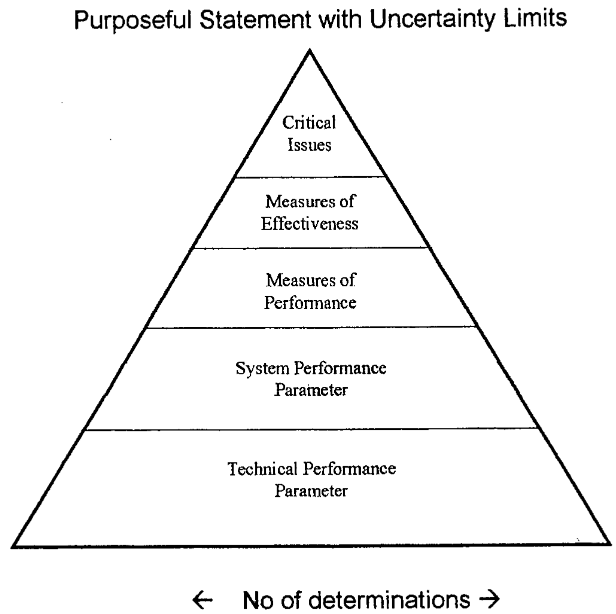

Fig 4. Generic Measures of the Measures Tree

As the various measures become better defined the overall uncertainty will improve. Examination of selected 'highlighted' measures will give IPT leaders and Capability Managers the crucial data they need to track maturity.

Sound logical considerations suggest these three concepts are all present in the same system so they must be capable of being mapped together to yield technical performance control information.

Having done that the **TEMP** goes a way toward defining how these three activities are integrated. However, being prepared for high level oversight study of several TEMP examples suggests there is insufficient traceability for the various measures to mapped back up the trees. Remembering that the only 'hard' data available comes from determination of the Technical Performance Parameters (TPPs) (with some more subjective numbers from the System Performance Parameters (SPPs)) traceable mapping is essential to use measures to track the maturation of the Critical Issues and thus closeness to customer needs. Any serious lack of traceable calculations leaved much in doubt.

It seems, in the USDoD T&E practices that the creation of the TPP and SPP parts of the T&E plan are carried out with less than openly obvious procedures. Army creates a Systems Evaluation Plan. Navy and Air Force construct the test plans using less formal methods.

A small group of DERA Ranges Sector staff enrolled in the MSc in Systems T&E at UCL are currently investigating improved integration of these key processes. Whilst their work is still in its early stages of development several key conclusions have already emerged from the assignment work.

- The SE process being used must be identified
- The T&E process must be used to develop the essential data requirements and test plans
- Measures Trees must be set up from the Critical Issues formed from customer requirements
- A TEMP document must be prepared that records these deliberations and having both downward and upward traceable mappings
- A sound explanation of the downward and later upward mappings is essential to show how to use TPP data as it maps from 'hard' quantitative data into the much more qualitative numbers of the MOP, MOE and CI levels.

A most significant concept developed by the group is the need to establish a Programme Critical Issues database. This database records the CIs, along with their Measures Trees and test plans. As each phase of a programme is developed it can also yield additional CIs of its own, earlier declared CIs grow in maturity and eventually outlive their usefulness to become the source of knowledge for other programmes. Fig 5 gives an impression of the T&E data flows for this purpose. This aspect is the subject of current study as this appears to be a novel, or at least extended, concept of the use of centralised metrics databases.

With such a dynamic T&E database the Programme Manager is then able, at any time, to see how the various CIs are maturing by appropriate use of the measures as they become available. This takes the well established Technical Performance Measures tracking to an improved level by the strict addition of traceable and scientifically sound creation for far more issues than TPMs usually cover.

<u>Summary</u>

Two salient ways to improve the CTP performance of major defence systems development have been presented.

1. Improved appreciation of the Knowledge flow aspect of SE activity to yield better team interfacing would significantly reduce design error early in the process where it is cheap to fix. This is, however, hard to put into useful practice because of the embryonic state of our understanding of the problem of knowledge transfer in communications networks.

2. More rigorous and traceable T&E practices applied to well defined SE process implementation would also lead to early error detection and control.

This can be implemented now as its features are well established. It will increase programme overhead somewhat but can confidently be expected to save those costs by virtue of less costly late errors arising.

Well-implemented T&E high level planned processes with a central database of CIs and Measures Trees have the potential to allow a programme to proceed through its phases with far less 'surprises' making metrics available that can be tracked and extrapolated to predict toward sound goals.

To do this well, however, needs a sound understanding of the SE process and this in turn makes its essential that T&E and SE leadership staff are well versed in both areas and that expert T&Eer's are involved very early in programme phases.

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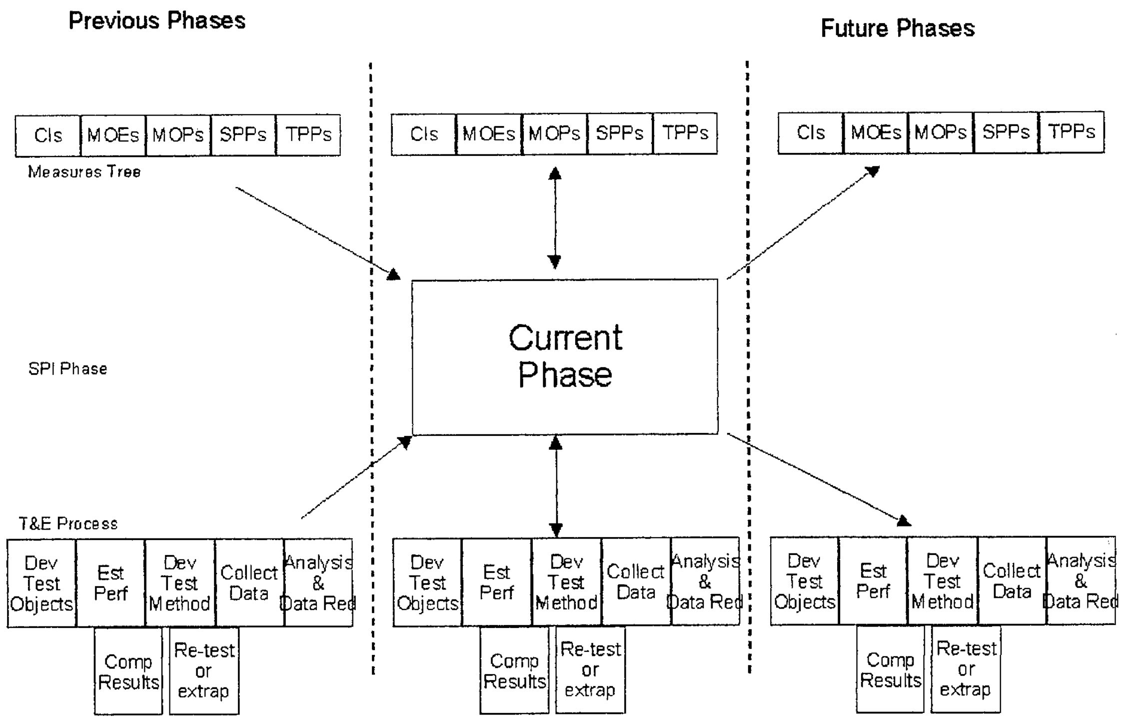

Fig 5. Overview of Critical Issues Database Flows used to Assist Control Technical Performance of a Programme. (From McDonald (2000))

Flight Test versus Flight Trials: Defining a Common Language for Operational Evaluation of Jointly Developed US/UK Systems

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FLIGHT TEST VERSUS FLIGHT TRIALS:
DEFINING A COMMON LANGUAGE FOR OPERATIONAL EVALUATION OF JOINTLY DEVELOPED US/UK SYSTEMS

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Abstract

The changing environment in world economies are creating the need for allied governments to work together to develop new weapons systems. Under these new development arrangements evaluation costs are often inflated because testing is repeated to satisfy the standards of two or more counties. The United States and the United Kingdom are the two countries most extensively involved on joint or cooperative development programs, however the standard models for operational evaluation vary greatly between the US and UK. US MIL-STD operational testing and UK DEF-STAN operational trials ultimately have the same goal of providing a complete weapon system which satisfies end-user needs while being affordable and maintainable. At the foundation of both the US and UK models is the Concept of Operations (ConOps) for the weapon system being developed. Beyond this point the models diverge. The US model provides for a clear break between Developmental Test, performed by the contractor, and Operational Test, performed by the military. It also requires the definition of strict Measures of Effectiveness (MOEs) and Measures of Performance (MOPs). The UK model allows for more interactions between the contractor and users during development and Operational Trials, and defines Trials into two categories: Single Activities Tests (SATs) and Multiple Activities Tests (MATs). These different definitions for operational evaluation are more alike than different at the day-to-day testing level, however the differences in language tend to create duplicate testing requirements to satisfy each country's' standards.

This paper will provide a basis for a common operational evaluation language by mapping the US and UK definitions and objectives to each other. Additionally the use of more closely integrated contractor/government teams, and synergies created by combining assets and understanding, will be presented as a way to streamline testing. This will create a foundation for a new model, which will satisfy the US and UK standards for operational evaluation and produce more effective testing, while eliminating redundancy.

The Challenge of Joint Development

We finished the FAA cert, and we thought we were done...then we sold the plane to the USAF and the RAF – Anonymous

Today's economy is becoming increasingly global and with it so is the defense industry. BAE now has an American and Canadian sector just as Lockheed Martin has a UK company. They remain, however, divided by national policy and law into separate operating companies isolated within specific borders. In general, no other multinational industrial base is so divided.

Add to this the regulations of the US and UK military and their respective procurement policies, and it becomes clear that any company seeking to develop and market a new military aircraft for joint use is facing many challenges. In most cases in the past those companies haven't even tried to save money, they just did the testing and documentation twice, once in the US and once in the UK.

The aerospace industry and the military can no longer afford this extravagance because defense budgets have been cut to their lowest levels in decades. Quality aircraft, which meet the mission needs, can, and should, be developed jointly.

The US DoD and UK MoD have more in common in terms of missions, and strategic and tactical objectives, than most other countries. Both the US and the UK have good and bad in their approach to development and testing. The models need to brought closer and the best practices of each used to facilitate joint programs, and do it once...right the first time.

Defining US Operational Test and Evaluation

In basic terms Operational Test and Evaluation (OT&E) is concerned with determining whether the weapon system meets the needs of the warfighter. OT&E tests to concepts, particularly the Concept of Operations. A good ConOps includes scenarios

which describe the basic mission of the system, its operating environment, range, payload, crew, armament, ground support equipment (GSE), support personnel, maintenance, deployability, mission planning, and weaponeering. This provides the planning basis for OT&E.

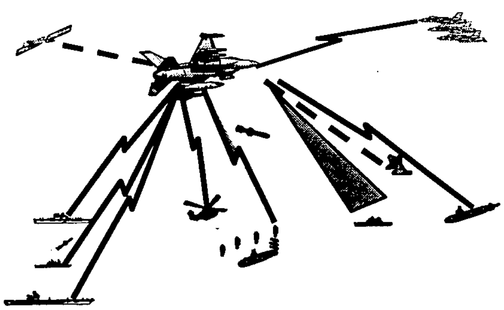

Figure 1 – Typical Concept of Operations

By US law, the Operational Test organization must be independent from the developing agency and contractors. This wall in the past has created a problem with "testing in a vacuum". Often the Operational Test organization is not strongly involved with the development phase and has not learned all of the nuances of the system by the time OT&E begins. Supporters of this method believe that it provides a more fair and accurate evaluation of the training and the system, while detractors believe the time could be used more effectively if the testers knew the system. Several newer programs have begun experimenting with bringing operational testers into the process during developmental testing. These experiments have tended, at least anecdotally, to field more mature, better-understood weapon systems.

In traditional programs where OT&E is separated from the developers, the Operational Test organization begins developing an Operational Test and Evaluation Plan by defining Critical Operational Issues (COIs). These are derived directly from the ConOps. A COI should address significant threats or needs for the new weapon system. As an example, a new surveillance and command aircraft may have a COI that requires it to track enemy aircraft at 300 miles in various weather conditions. The COI is derived from the need to keep the aircraft outside of hostile airspace where it can be protected. Another example of a COI might be that a cargo plane must land on short, unimproved landing strips, with a full payload. This COI allows for the aircraft to support deployment into remote areas.

OT&E does not traditionally test "shalls" from the system level, or lower level, specifications. Performance criteria may be derived from development specifications, but they are couched in the total mission environment, not taken as an absolute. For example, a subsystem specification may require that in standard-day conditions, at sea level, an engine will develop 80% thrust at an exact throttle setting. This requirement, tested in an engine cell, or even in developmental flight testing under controlled conditions can be verified with great certainty and accuracy. In an operational environment, however, that same engine may never again be exposed to a standard day condition. The throttle rigging and the fuel flow sensors may have marginal errors induced by maintenance, all of which will add up to a slightly different efficiency for the engine performance. Operational test in this example would determine whether the engine efficiency under real-world conditions was within acceptable limits.

OT&E also provides a valuable period where the warfighter gets a last look at the system prior to fielding it. This can translate into many useful insights that can be added to flight and maintenance manuals, and training materials. Many times, when a new system begins OT&E, the ConOps is refined. This occurs because inevitably the system will provide features and capabilities which were not discussed in the original ConOps.

Typical OT&E Progression

System Assessment OT&E generally begins by evaluating whether the system works as advertised. Do the computers boot? Does the radar run and detect targets? Can the aircraft carry its basic payload over the required range? Many of these items are, in the US model, included in the Measures of Performance (MOPs) laid out in the Operational Test and Evaluation Plan. Often these MOPs are closely tied to the functional and performance requirements used during developmental testing, but modified to the real world as discussed earlier.

Mission Effectiveness After the basic aircraft and support functions have been evaluated, OT&E begins to explore whether the total weapon system can be effective to perform its mission. In many instances this is the phase when the understanding of that mission begins to evolve into operational plans. This phase includes final Human Factors evaluations, reliability, and measurements of operating limits such as mission duration and climate extremes. In the US model, this phase typically completes the MOPs while it begins evaluation of the Measures of Effectiveness, (MOEs).

Integrated Sorties The final phase of OT&E provides evaluation of complete mission scenarios. In this phase all components of the system are brought together and the system is integrated into the final force structure. The scenarios are

constructed to evaluate the complete cycle beginning with crew training systems, mission planning, staging, coordination with other units, interoperability, mission performance, post-flight activities such as maintenance and turn-around, and suitability issues. This is generally the phase where the end-users begin trying limited deployments with the aircraft, and experimenting with alternate employment of the system. The final evaluation of the MOEs is generated during this phase.

Feedback The Operational Test and Evaluation Test Report provides the basis for long-term use and maintenance of the system. Typically a contract is in place for Contractor Logistic Support (CLS) which will provide for Correction of Deficiencies (COD) found during OT&E. Additionally, planning begins for future improvements based on ideas and uses developed during OT&E. Developers and users also use this phase to collect Lessons Learned, both as they apply to the development and testing and to the system itself. Maintenance procedures, tech pubs, users manuals, and checklists are updated with information developed during OT&E. And finally the ConOps and mission of the system are refined, ultimately completing the cycle.

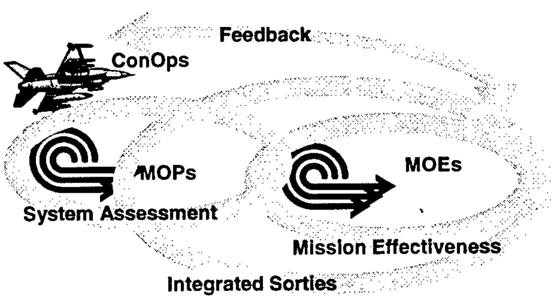

Figure 2 – US Operation Test Phases

The UK Definition - Operational Trials

Operational Trials (OT) are designed to give the Military Service units hands-on evaluation of the aircraft/weapon system. OT starts with the Concept of Operations. The UK use of the ConOps approach during Operational Trials is almost identical to the US usage. Each new system is evaluated for its suitability and utility for the planned mission environment.

The UK approach allows the MoD Procurement Executive (PE) some flexibility in assembling the Operational Trials team. The team can be comprised of Contractors, Service Units, DERA, and other groups as appropriate. All team members may contribute to planning and executing the Operational Trials program. This leads to a more cohesive test organization with a better-defined understanding of both the strengths and weaknesses of the system.

Timing of Operational Trials may also vary depending on the program. Service units may begin evaluating the system well before Military Aircraft release and may in fact perform initial Operational Trials in parallel, or in conjunction with, developmental trials. Parallel phasing tends to ultimately field a more mature system concept at completion by finding operational flaws earlier.

UK Operational Trials Progression

System Assessment Operational Trials begin with Single Activity Tests (SATs) which concentrate on performance of individual systems. These are typically functional assessments which verify, under slightly different conditions, the results of the development trials.

Mission Effectiveness The next phase begins to integrate the basic aircraft with its supporting equipment and personnel. The aircrews, mission planners and maintainers begin to evaluate suitability and military utility. Formal trials begin to transition from SATs into short, limited Multiple Activity Tests (MATs).

Integrated Sorties To complete OT the length and the scope of the MATs are increased until they embody complete, mission representative sorties. This may include deployment to a forward operating base and transmission of mission data to a surveillance organization. Each user in the mission planning, execution, and maintaining process has an opportunity to evaluate the effectiveness of the system for the planned operational employment.

Feedback The Operational Trials structure allows for continuous feedback to the contractor and the service units about the progress of the testing and the system. Correction of Deficiencies may be performed throughout OT. When the MoDPE deems that the system is sufficiently mature and meets an acceptable level of requirements, the system is released to the service units.

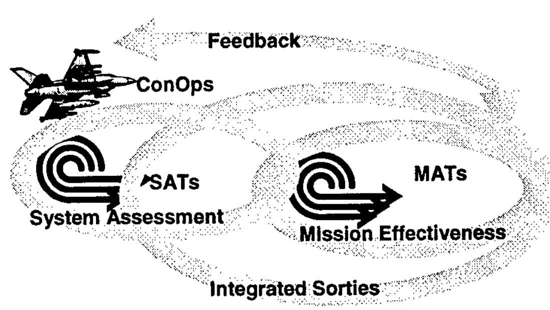

Figure 3 – UK Operation Test Phases

Concepts Not Words

The above definitions indicate clearly that the major differences between the US and UK, at least at the top level, are the titles of the tests and test criteria. There is a fundamental progression of testing which can be used to map the US MOPs and MOEs to the UK SATs and MATs. The underlying concepts are the same and laid out in the same order:

- System Assessment
- Mission Effectiveness
- Integrated Sorties
- Feedback

Why then is it so difficult to bring these approaches together in practice? National and company arrogance is certainly part of the problem. There is a decided US-centric and Anglo-centric attitude apparent when dealing with either country which brings a level of confrontation into the day-to-day dealings on joint programs. Also, within the contractor community there is an attitude which routinely ignores customer requests and real-world military experiences. This is the "we'll tell you what you need" attitude. None of these attitude issues can be corrected or even addressed without creating an environment of understanding between all of the parties involved. There must be a common starting point for discussion and planning.

Who Does What? When?

One starting point should be to clarify and standardize the roles of each organization involved in operational testing. Some compromise between the various approaches and levels of participation needs to be developed. In the era of limited defense budgets and downsizing, performing testing two and three times is a waste of valuable national resources.

As discussed earlier, the US methods typically require that the OT organization be completely isolated from the development effort. When the development flight test phase is nearing completion, the operational test crews, both maintainers and flight crews, are sent through training using the contractor developed training material. Once they have completed the course work they are handed the aircraft and told to evaluate it. With specifications and ConOps in hand, they plan and fly their missions. In this environment with no hands-on time or history with the aircraft and its nuances, sorties are typically ineffective, maintenance suffers, and most new aircraft receive a poor initial rating. The contractor is called in, in crisis mode, to "fix" all of the deficiencies. During this crisis recovery process the OT crews are finally introduced to the system and often withdraw most of their original objections and complaints. They begin to see the system as a whole with all the complexity that the initial training couldn't give them. Unfortunately by this time bad press and political wrangling have started and the aircraft never achieves its full potential.

As mentioned earlier, in the UK the timing and roles of operational testers are much more flexible, frequently allowing for some combined DT/OT or at least contractor involvement in testing. This process creates a feedback loop much earlier in system development. It also tends to lead to better training materials, more hands-on time, and more experienced crews. Contractors also develop better understanding of the operational fielding requirements because they are directly involved with the service units. With both contractor and service unit involvement, the ConOps is refined and updated, ultimately providing a more effective weapon system.

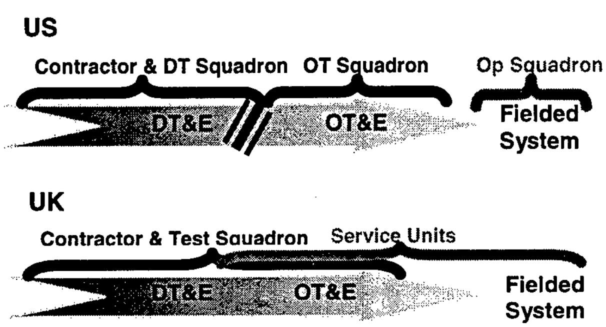

Figure 4 – US Vs UK Test Team Participation

During the B-2 program the US experimented with this combined DT/OT approach and was able to field a more mature aircraft with better trained crews. Maintainers and aircrews ultimately destined for the operational squadron at Whiteman AFB, were the initial OT&E crews at Edwards AFB. They participated in DT missions as well as planning their own sorties. An effort was made not to duplicate DT testing with OT missions but rather expand and enhance what had been done before. When the aircraft were delivered to Whiteman AFB, the tactics and staging strategy of the aircraft were fully developed and the aircraft achieved Initial Operational Capability (IOC) quickly. This approach also provided a solid understanding within the development community of what upgrades and contractor logistics support (CLS) would be needed long-term. During the bombing campaign in Kosovo, this method paid off, resulting in the B-2's stunningly high sortie and targeting rate. These results have never been achieved in military history, and can be attributed to the

effective development, testing, and training in the B-2 program.

This evaluation indicates that the most effective operational test or trials programs allow early participation by the operational units in the flight testing and continue to allow contractor involvement during formal trials. This provides a more enlightened atmosphere for development and fielding on both the contractor and military sides. It also reduces overall test costs by testing the system in a continuous feedback environment which evolves and develops the weapons system, training, tactics, and strategy throughout the trials program.

Big Words, Bigger Differences

On the C-130J the plan is to perform a Joint USAF/RAF/RAAF test program aptly named "Operationally Representative Strategic Workload Tests". The intent is to demonstrate that the C-130J workload concept does not overstress a three-person crew. The proposed concept uses two pilots and a system specialist who serves as both flight engineer and load master. Previous C-130 models used a five-person crew: two pilots, a navigator, a flight engineer, and a loadmaster.

The joint test concept began well and all of the major plans were agreed to by all parties. Then the detailed planning began and soon it was determined that each test had to be flown twice or three times because each air force had to "independently" evaluate the test points to achieve their OT objectives.

Some of this re-fly was reduced by various services agreeing to ride along and witness some tests. This is feasible on a C-130, but not on a fighter like a Harrier. In that case, the services would have to agree to mixed crews or even acceptance of each others evaluations during various flights. While this does not seem unreasonable, national laws may make this a requirement. These requirements are intended to protect the services from receiving ineffective weapon systems, but should allow for flexibility during joint programs where each service has essentially the same mission objective in mind.

The next major obstacle, which has yet to be resolved, is the definition of "operationally representative". One of the three participating air forces have stated that, in a workload assessment, the aircrews may not know in advance what "tests" will happen during the mission. In addition, the route flown cannot be pre-planned because the crew must be free to make their own divert/rerouting decisions. Obviously, within the highly controlled airspace environment and the needs of flight test, this re-route issue can become nearly insurmountable.

A mission scenario might consist of take-off with a 40,000-pound payload with an intention to do an airdrop 5 hours into the flight at a specified military facility and a return to base. The airdrop test would require chase aircraft, range safety and security sweeps, etc. The workload assessment test would induce a simulated engine failure which would create the need to dump the load at the earliest possible time. It becomes obvious, due to the range safety and support requirements, that the cargo must be dropped at the pre-planned drop location. The aircrew flying the test does not get a choice in this, other than to bring the cargo home, and this is the issue which can not be resolved. Is the aircrew, knowing from the outset exactly when and where the cargo will be dropped, psychologically challenged enough for this scenario to be operationally representative?

One air force believes it is, while one doesn't, the third hasn't expressed an opinion, and the contractor can't complete the contract until they agree. The challenge is to reconcile the definitions of operationally representative and provide the support and mission scenario that can accommodate the requirements of the participants. Though only in the planning stages, the scenario described above must be resolved before testing can continue. This scenario could be performed in the US western test ranges, where it could be arranged to have multiple cargo drop options on a single mission. The crew could then drop the cargo at one of several locations during their simulated emergency. This approach quickly becomes expensive, because multiple sets of support will be required to allow the test to be completed with all of these optional ranges.

This method also does not address the core issue of what is truly operationally representative. Even with multiple possible drop points, the crew is still limited in their choice. In a real mission, with a real engine failure, an aircrew would drop as soon as possible, perhaps trying to avoid populated areas or enemy encampments, but with regard for little else. In the test environment they have to choose from a few options and know prior to the mission that something will "happen" during the test to force them to choose one. They will be briefed on procedures for each drop range, communications procedures, etc. Does this prior knowledge contaminate the test results? Or do the additional requirements for communication and coordination during the test emergency add enough to the workload to create the required level of psychological stress?

There are no easy answers to this question. The participants need to be willing to explore what is possible and feasible and come to a common definition. Flexibility in defining "operationally representative" will be the key to a compromise that

will meet both requirements and budgets. On the surface, it would appear that substitution of one type of workload for another would have to satisfy the requirement. This philosophy is certainly consistent with previous operational testing. No peacetime simulation can ever fully recreate the psychological stress of war, or the workload involved in a volatile environment. This means that "operationally representative" testing is performed to whatever level is feasible and cost effective and that true crisis situations are never really simulated.

A Hypothetical Test

In the world of operational testing, each aircraft must eventually undergo what is typically the hardest and most demanding of all operational trials; the multi-ship forward deployment. This test requires involvement from all parts of the weapon system and its support organization. It also integrates the system into the operational organization, such as other aircraft and squadrons that will support it, or that it will support. This type of test also provides the backdrop for most disagreements in joint development programs because each country has a different definition of what constitutes a Forward Operating Base (FOB) and how the aircraft will be integrated into operational tactics.

The challenge is to define a test which brings all of the elements together. It should be conducted with a joint team letting each member evaluated their particular area of interest. It should combine as many resources as possible. It should be based on common understanding of the mission roles and responsibilities and use common terminology and definitions.

In this hypothetical example, the aircraft is a new surveillance platform which can gather radar, optical, and infrared (IR) imagery, but not at the same time. The aircraft sensors need to be reconfigured depending on the mission requirement. In the radar configuration, the mission system can quantify and track individual ground units and moving vehicles. The US surveillance doctrine places great emphasis on the quantified radar data, allowing computers to do most of the analysis and tracking of the enemy units, and disperses these data directly from the aircraft to the field units. The UK doctrine is designed around an intelligence organization of centrally located analysts that evaluate primarily the optical and IR imagery and then disperses tactical and strategic intelligence back to the field. The aircraft under test has the equipment on board to support both types of operations but not simultaneously. The tactics require that a platform is on-station at least 18 hours out of 24. Each aircraft has a useful mission duration of 12 hours which include ferry from and to the Forward Operating Base (FOB). The FOB is assumed to be in friendly territory but within 2 hours flight to the front lines. All of the support equipment, a deployment kit, including mission planning, data and imagery processing, and spares, must be transported to the FOB, along with the personnel required to provide this support. The mission requirements include a response time from initial crisis notification to full deployment and station keeping.

The challenge of the joint test organization is to reconcile the differing doctrine of the two air forces and create one deployment test that will satisfy the requirements of both. The test is an integrated sortie by the previously described definition. In the US test methodology it would be evaluating primarily MOEs. For the UK the test is defined as a MAT. A possible scenario to satisfy all requirements could be developed along the following lines.

One sortie will be used to demonstrate FOB Deployment. This will include the quick response of the aircraft deployment to the FOB, drop off of extra crew, aircraft quick-turn and on-board/enroute mission planning. The ground station will be transported to the FOB and the set-up/response time, establishment of Main Operating Base (MOB) command/control links to the FOB, and MOB/FOB support for the deployment will be evaluated.

After extra crew drop-off, the aircraft will proceed to a crisis-intervention data collection mission. The ConOps defines the optimum crisis-intervention configuration as radar but the aircraft is configured for optical and IR imagery. No preplanned mission will be available and the scenario assumes that the aircraft is not in the preferred configuration. This mission will exercise command links from the FOB to the MOB, both ground station and aircraft responsiveness to a highly dynamic reconnaissance environment. Primary objectives will be to evaluate crew workloads, Optics package suitability to the real-time environment and interoperability with various command and control segments.

A second aircraft will also deploy in the radar configuration, several hours later. This aircraft will rendezvous with the first aircraft on-station and relieve it with a voice and data handover. The two aircraft will exchange the Area of Responsibility (AOR) between an Optics equipped aircraft and a Radar equipped aircraft and will include all ground station and command coordination. An air-to-air data transfer is planned as is an air-ground-air data transfer. The primary objectives include datalink evaluations, crew procedures, checklist verification, and tactics development.

The Radar surveillance mission will generate target tracks and Synthetic Aperture Radar (SAR) data

which will be analyzed on board the aircraft. These data will be used by the on-board mission commander to give voice only target co-ordinates for air and ground strike support. The primary objectives of this mission will be to demonstrate the mission suitability of the radar functions for strike support and targeting. No preplanned mission or Ground Stations will be used.

On return of the Optics aircraft from the imagery collection, the Ground Station should be operational, all mission/aircraft support equipment should be in place, and a relief aircrew should be ready to take the aircraft. The aircraft will be prepared for a sensor change to reconfigure it to the radar configuration. The actual sensor change-out will be performed at the FOB. All support structures, mission planning, communications and data co-ordination, and ground station reconfiguration will be evaluated. Additional objectives will be verification of maintenance procedures and crew co-ordination. The sensor change-out and reconfiguration to radar support should be completed in time to support another sortie to relieve the original radar aircraft on station.

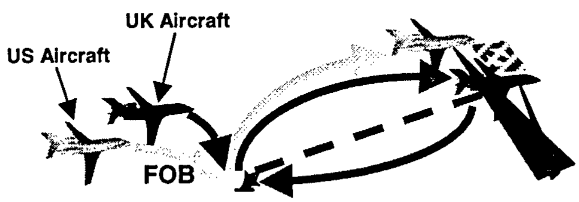

Figure 5 –Joint Deployment Test

This scenario is highly complex, involves numerous support elements and intricate test planning. Nevertheless, the complexity allows the test to satisfy the mission requirements of both services with one series of sorties and a single deployment. Each service involved flies the sorties which are most applicable to their particular doctrine: UK on the Optics mission, and US on the Radar mission, with both services participating in the deployment, maintenance, mission planning, and data processing operations. By planning the division of labor in this way, all of the overall objectives are met and each service can evaluate their particular mission requirements. The joint operation clearly emulates a real crisis situation in which both countries might respond. In a joint crisis response they would have to coordinate their data gathering, tactics, and logistics in just such a way. Finally, using this approach, both MOEs and MAT criteria are satisfied when the test is successfully completed.

Recommendations

On future joint development programs, and current programs where the requirements and contracts are flexible, the operational test and trials should be designed to satisfy the most requirements and deliver the most mature system possible. This can be achieved by using common definitions and organizational structured based on the best practices of both the US and UK.

Organization Definition Create a joint test/trials organization that includes the contractor as well as both services. This provides a closed-loop feedback system. The contractor products, including training materials and aircraft and maintenance manuals will be better suited to the warfighters and maintainers using this approach. Clearly define participants' role in the joint test team, and assign them tasks that use their strengths.

Test Timing Begin Operational Test and Evaluation during later stages of development testing so major deficiencies are addressed earlier in the process. Build on the developmental testing rather than repeating it.

Common Phase Definitions Define the operational trials phases as System Assessment, Mission Effectiveness, Integrated Sorties, and Feedback. If required by the contract, a matrix can be created which maps the MOPs, MOEs, SATs, and MATs into each test defined in these phases.

Use All Of The Resources Plan and perform tests which take advantage of the differences in doctrine and approach. Not only does this allow each country to evaluate their items of interest, but it will also highlight how the doctrine and tactics differences will dovetail, or perhaps conflict, during real-world joint operations.

Create a Dictionary During the initial planning stage, all team members should jointly create and agree on common definitions. Terms such as "operationally representative", "witnessing versus participation", and "strategic workload" should be as well defined as the performance numbers in a specification. This prevents disagreements during planning and testing. All participants will be working from a common language.

Supporting the Warfighter: "Testing the Way we Fight (and Train)"

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SUPPORTING THE WARFIGHTER
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Abstract

The United States Air Force is changing the way it both acquires and employs new systems; precipitant is a re-engineering of its Operational Test and Evaluation (OT&E) methodology. Two circumstantial alterations compelled this methodological adjustment. Streamline acquisition initiatives, such as Advanced Concept Technology Demonstrations, Battlelab Initiatives, Evolutionary Acquisition, and Commercial and Non Developmental Items (CaNDI), are rapidly reducing the timeline associated with the development and subsequent fielding of new capabilities to the warfighter. Secondly, the arena in which new capabilities are fielded has become increasingly joint and multi-national, as evidenced by military actions during the last ten years. This arena requires an intricate understanding of how a designated weapon system will be used and maintained, as well as identifying which missions this system will supplement in combat.

Shorter development times, reduced resources more sophisticated weapon systems, and employment in an increasingly complex environment presents operational testers with a tremendous challenge--cost-effectively replicate the warfighting environment to simultaneously support the acquisition decision for long-term procurement and provide operationally useful information to the warfighter.

As the US Air Force organization responsible for OT&E, the Air Force Operational Test and Evaluation Center (AFOTEC), has incorporated a new approach to define and optimize operational test and evaluation. The first step, researches battlefield operations and the system-under-test (SUT) in terms of its design and the mission(s) it is intended to supplement, and identifies the interaction with other systems required to successfully accomplish operational tasks in support of the mission. This analysis identifies the significant impacts of the SUT on the mission, and the complimentary mission effects on the SUT. Given this foundation of understanding, AFOTEC implements the second phase of the approach. In this phase a team evaluates the analysis and determines the appropriate level of testing required for the SUT, based on the value of the information, impact to the mission, test venue opportunities and of course, constrained resources.

The result of this approach is an OT&E designed to provide both sufficient information to the acquisition authority to support a full-rate production decision and provide insight to the warfighter on advantages and disadvantages to successful mission accomplishment. The latter, called Operational Impact Assessment (OIA), may or may not be due to the introduction of the new system and its capabilities. This paper will provide an example of this process and highlight the advantages, through increased information, to both the acquisition decision-maker and the ultimate customer, the warfighter.

Background

Operational Test and Evaluation is an integral part of the acquisition process. OT&E provides both the acquisition decision authority, Major Command (MAJCOM) and the warfighter with valuable information on the deployment, employment and sustainment capabilities of new systems. United States public law mandates independent evaluation by operational testers for all major acquisition programs. An independent report is published prior to production and fielding of these defense systems.

The Business of OT&E

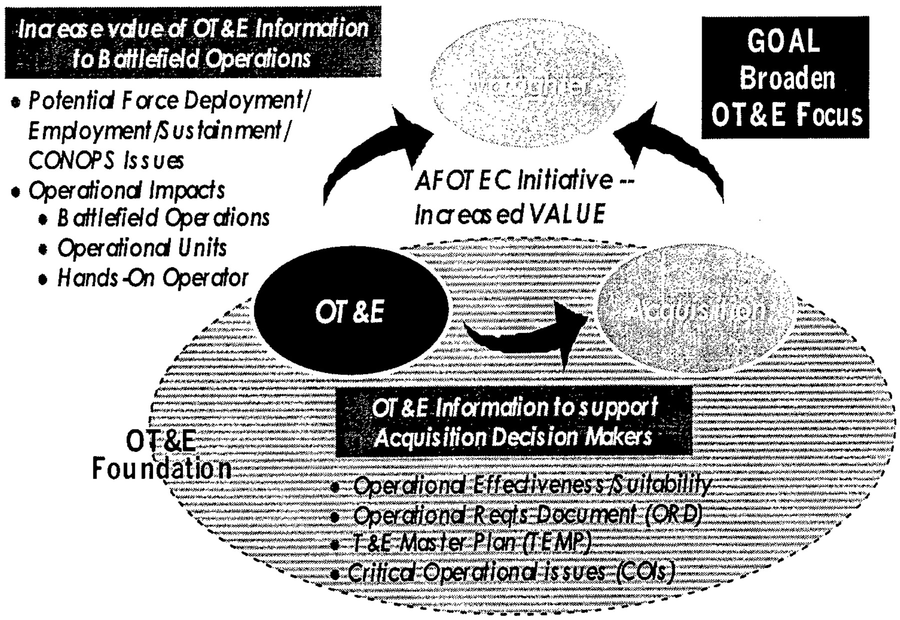

Figure 1: OIA - The Concept

The business of OT&E is to provide information to both the acquisition authority and the warfighter. To effectively provide this relevant information the "O" in OT&E must be the focus. Any OT&E with a strong foundation in operations will lead to an evaluation focused on the warfighter's needs. Finally, any evaluation must be founded in accurate and complete test data. We must always keep in mind, however, that tests generate data and the evaluation produces information.

Operational Impact Assessment (OIA)

The Concept

As seen in figure 1, the foundation of OT&E is to address system effectiveness and suitability in an operational environment, and support the system acquisition process. The new approach, however, is to expand this circle to increase the value of OT&E information to battlefield operations for the warfighter. Figure 2 shows where OIAs fit in the overall structure of test and evaluation (T&E).

Developmental and Contractor Test and Evaluation (DT&E/CT&E) is performed by the development community (contractor and/or the government). This aspect of T&E focuses on evaluating system performance against specifications in the contract that are based on the user's operational requirement documents (ORD). OT&E, by law, refers to (1) the field test, under realistic combat conditions, of any item of (or key component of) weapons, equipment, or munitions for the purpose of determining the effectiveness and suitability of the weapons, equipment, or munitions for use in combat by typical military users; and (2) the evaluation of the results of such test." Hence, traditional OT&E emphasized system-level effectiveness and suitability. The SUT was evaluated in an operationally realistic environment with a focus of determining how well the system actually worked when operated and maintained by real "operators". Considerations outside of the stated system operational requirements were often not considered.

Ensure that we think through all aspects of employment - not just 'does the system work'...Gen Cliver

As presented in a January 1998 International Test and Evaluation Association (ITEA) article, Maj. Gen. Cliver (AFOTEC commander at the time), described the focus of OT&E as too limited since it did not provide adequate information across the full spectrum of the system acquisition and employment processes. The new focus on OIA was a significant change from the way AFOTEC had done business for nearly 25 years.

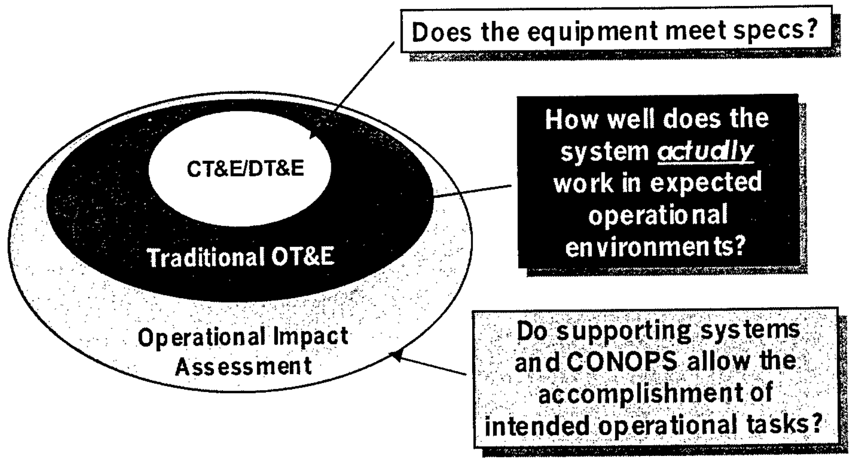

Figure 2: T&E Focus Areas

OIA, the third evaluation area in figure 2, is the new emphasis at AFOTEC. It is not limited to an evaluation of the SUT. It includes the potential impacts on battlefield operations, deployment/employment/sustainment considerations, and the interoperability issues introduced by the complexities of joint system-of-system environments. That is, OIAs look at other systems "feeding" the SUT (such as C4I and intelligence systems), and other systems dependent on output from the SUT. OIAs can identify holes and shortcomings of the larger system-of-systems for the warfighters. These assessments involve an interdependent, system-of-systems viewpoint of joint and/or multi-national interoperability issues and operational plan/concept plan (OPLAN/CONPLAN) observations, in addition to traditional OT&E. In short, an OIA provides the warfighters (e.g., Commanders-in-Chief, Joint Forces Air Component Commanders, Commander Air Forces) an assessment of the system's contribution to mission effectiveness and suitability in a joint, coalition, system-of-systems operational environment.

In order to develop a thorough evaluation structure, operational testers must understand battlefield operations as well as the system

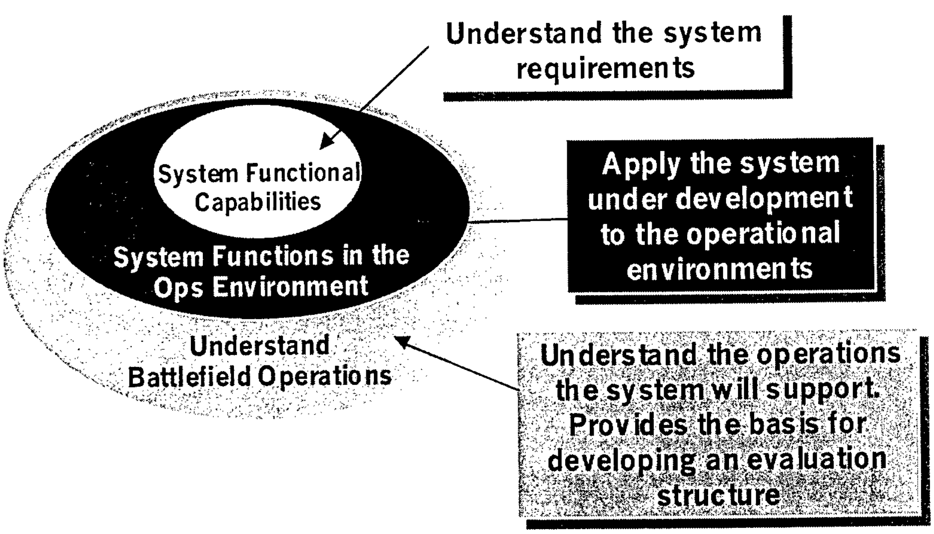

Figure 3: Developing the Evaluation Structure

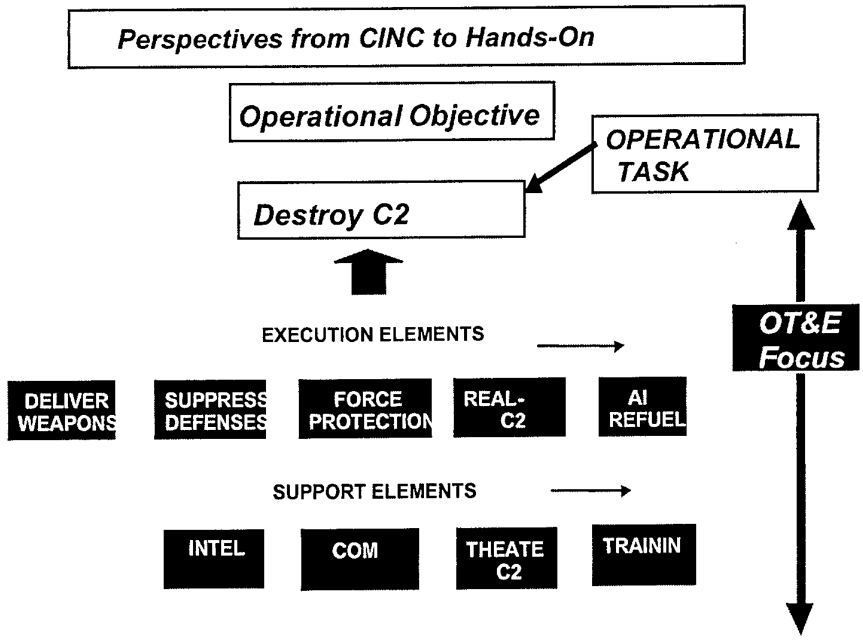

Figure 4: Understanding Battlefield Operations

requirements and functions in an operational environment as shown in figure 3.

In the earliest stages of AFOTEC's involvement, core teams are formed to research and collect system information from various sources to include the mission need statement, ORD, system concepts of operation (CONOPS) and maintenance, and system program office documentation/ discussions. This is a precursor to understanding where the SUT fits into battlefield operations and to understand system operating capabilities and limitations. The operational significance of the ORD parameters needs to be sufficiently understood in order to scope the evaluation to meet acquisition requirements.

The first step in understanding battlefield operations is to identify the operational task(s), the system under development will support. The next step is to breakdown the operational task into its execution and support elements. An example of these first two steps is shown in figure 4.

The goals of understanding battlefield operations are to: (1) identify operational objectives and associated operational tasks supported by the system, (2) understand any significant operational issues from the warfighter's perspective, associated with accomplishing the operational tasks, and (3) understand how execution and support elements work together to support the accomplishment of the operational task. This understanding is essential for determining the following operational impact considerations:

- Execution and support element impacts on the operational task
- Execution and support elements impacts on each other
- System impacts on the execution and support elements
- Execution and support element impacts on the system

This step, called a Risk/Impact analysis, identifies the major impacts on accomplishing the operational task.

<u>Implementation Process</u>

In addition to developing an innovative OIA approach, AFOTEC has also developed a thorough implementation process (figure 5). A core team of operational testers is formed to work each step of the process.

The first steps in this implementation process are to understand battlefield operations and perform a system introduction. To **understand battlefield operations**, the operational testers must fully address joint warfighting issues and the operational objectives/tasks that the SUT will support. In addition, functional mission decomposition must be completed to fully

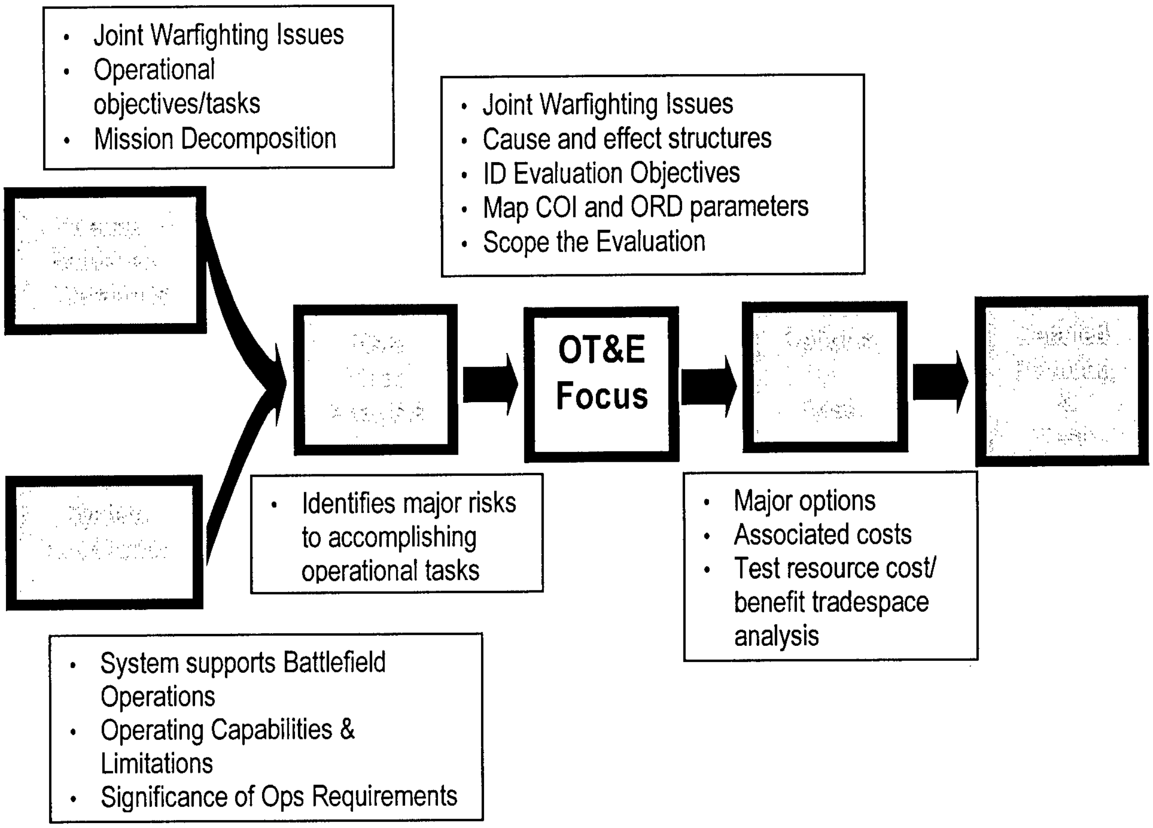

Figure 5: Implementation Process

understand battlefield operations. The **system introduction** consists of understanding the operating capabilities and limitations of the SUT, the significance of the operational requirements, and how the system relates to battlefield operations. The **risk/impact analysis** performed by AFOTEC identifies the major risks/impacts associated with accomplishing the operational task(s).

Once the major risks to accomplishing the operational task have been identified a "cause and effect" structure is developed around these risk areas to understand the sufficiency of conditions that could lead to a failure to accomplish an operational task. This process, called **OT&E Focus**, identifies the evaluation objectives since they normally show up as critical nodes in the structure. The ORD parameters and Critical Operational Issues (COI) are then mapped into the cause and effect structure since they must be addressed to support the acquisition process and to ensure that any "system critical" area has not been overlooked. Finally, boundaries are drawn around parts of the evaluation structure as the initial scope is proposed based on the potential value of the information. This last step requires significant test and operational experience.

During the **options and cost phase**, AFOTEC examines the major test options available (i.e., open-air testing, modeling and simulation, and test facilities or a combination in a distributed environment) and their associated costs. Once the test options are identified, AFOTEC conducts a cost/benefit tradespace analysis to select the optimum option available. Having determined the OT&E focus, AFOTEC allocates the appropriate test resources and transfers the test program to the appropriate field detachment for **detailed planning and test execution.**

For the execution phase, AFOTEC is augmenting traditional operational testing methods by increasing involvement in joint exercises and experiments in order to test in a more stressing, realistic joint operational environment. AFOTEC is also investigating opportunities for increased integrated testing of systems with Army, Navy, and Marine Operational Test Agency test forces. Again, the central focus of operational test and evaluation is on the system's contribution to mission

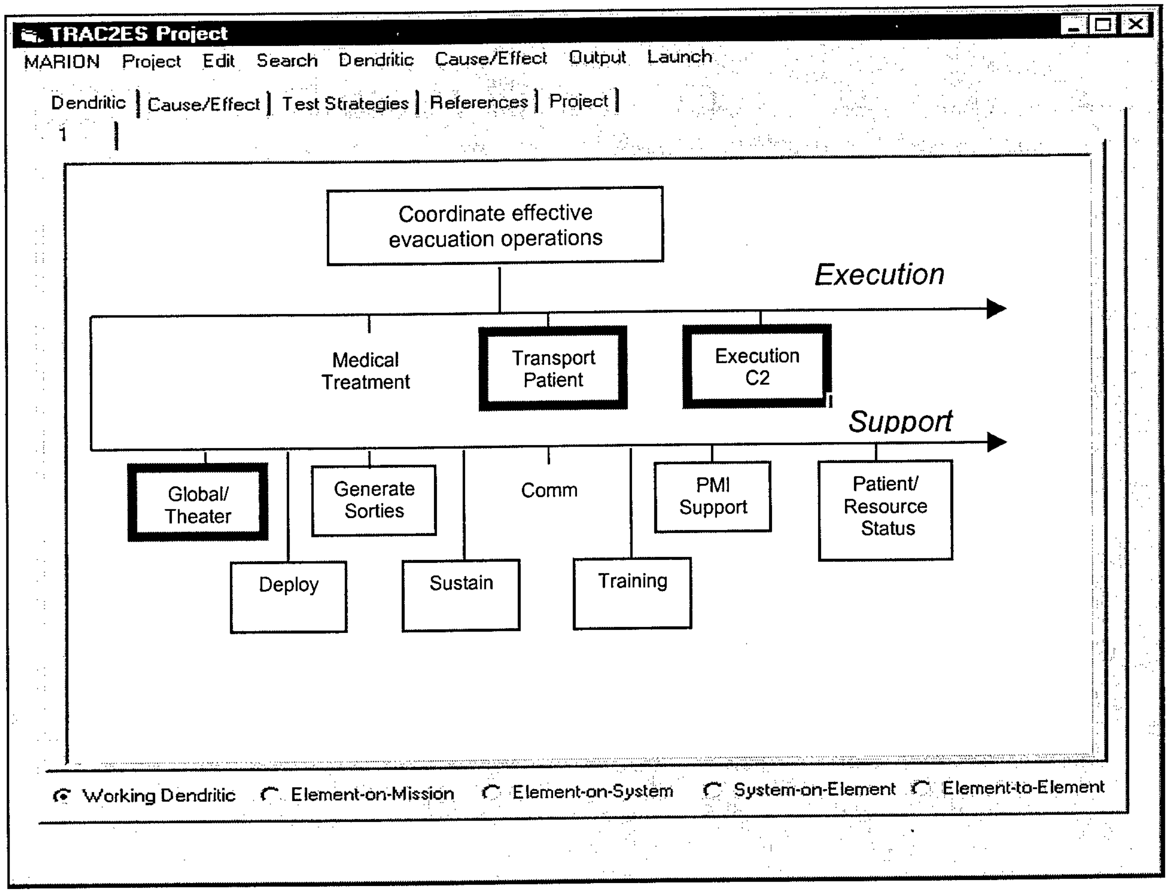

Figure 6: MARION Tool - Mission Decomposition

effectiveness and suitability in a joint, coalition, system-of-systems operational environment.

Implementation Tool

To support this process, AFOTEC developed a software tool called Mission Analysis and Risk Impact on Operations Net (MARION). The MARION tool is based on mission decomposition and considers the overall mission that the SUT supports. Once operational testers define test measures, the MARION tool supports selection of the optimum methods to gather the necessary and sufficient test data to support the evaluation.

As seen in figure 6, the tabs along the top follow the major steps of the implementation process, with understanding battlefield operations and system description incorporated into the Dendritic tab. This provides a "digital" representation of the mission functional decomposition, allowing the development of mission areas to be shared between programs. Also at this time, questions in terms of overarching mission perspectives and specific system requirements can be 'attached' to the different boxes of the decomposition for use later in developing test strategies.

Recall the purpose for the decomposition is to develop a common understanding between all players. MARION will augment the process by allowing previous work, for similar missions, to be "copied and pasted" into new programs, automatically linking the programs. The OIA process can be applied to any OT&E program. The example shown in figure 6, is a tracking system for patients requiring medical treatment.

The "radio buttons" on the bottom facilitate the Risk/Impact analysis. Again, this provides a methodology for understanding the importance between elements of the decomposition, both in terms of the operational mission and the system-under-test. By viewing the interactions from the four perspectives, Element-on-Mission, Element-on-System, System-on-Element, and Element-

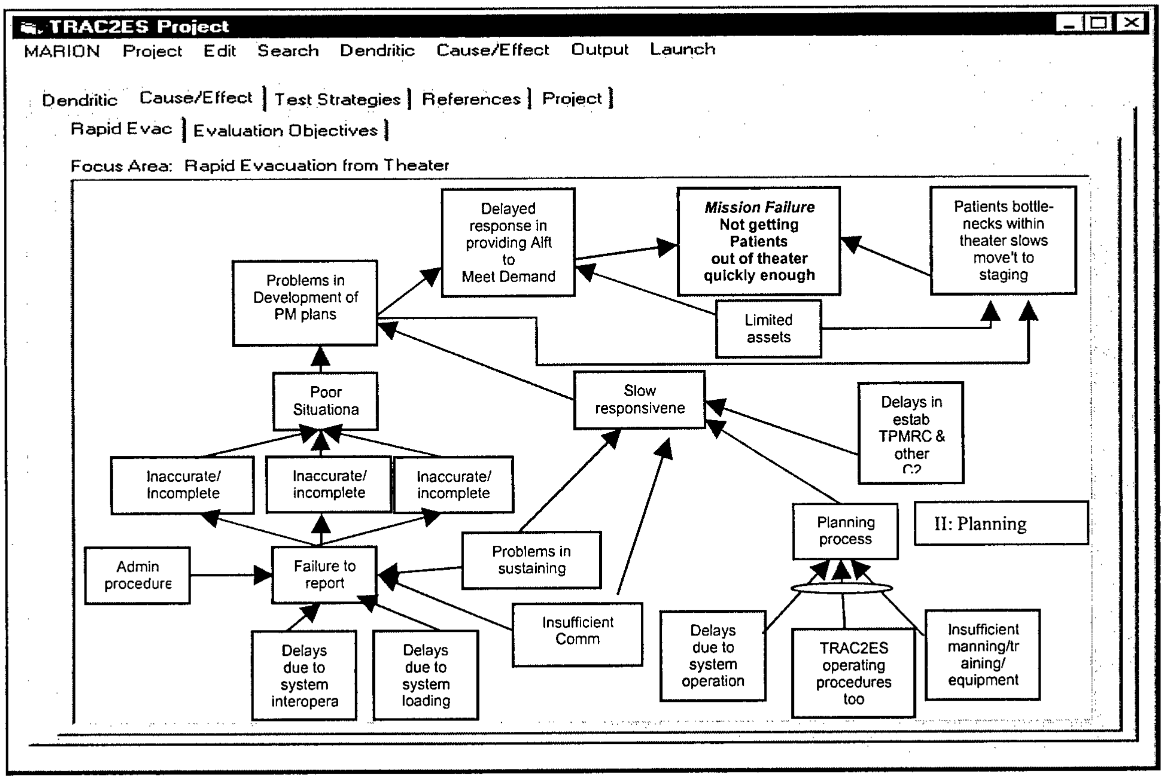

Figure 7: MARION Tool - Cause and Effect Analysis

on-Element, a broader perspective can be generated to identify the most important parameters, in terms of operational significance, to evaluate during OT&E.

For example, as shown in figure 6, for the mission decomposition and looking at Element-on-System impacts, those outlined in red (Transport Patient, Execution C2, and Global Theater C2) are rated operationally significant, and those outlined in yellow (Medical Treatment and Comm) are rated operationally relevant. The core team determines these ratings. One can relate these ratings to the relevant weight associated with that element to overall mission completion.

Additionally, with Element-to-Element impacts, the tool can track the rating of one element on another. The rationale for this rating, and any associated questions and measures are stored in a database for use in the Cause-Effect Analysis and to determine the coverage associated with specific test strategies.

The Cause-Effect analysis, with a basis from Theory of Constraints, links mission failures to the previous steps. The data from the previous steps is available to help make the associations, and the tool also allows comments to be associated with each of the links. The knowledge gained from the previous steps is applied to generate the diagram in figure 7. In addition, the information stored in the database is available for review, and can be modified at this stage to support the evaluation structure development.

The final development of the MARION tool requires a methodology to gather data to substantiate the evaluation objectives and structure developed in the Cause-Effect analysis. The proposed solution will identify the evaluation objective and use the database information to identify the measures and questions generated during the decomposition and risk/impact analysis. The options available to gather this data will be supplied by the database, to include similar options from other test programs. These are then aggregated to define separate test strategies, with its associated attributes of cost, schedule, and amount of information provided.

These strategies can be reviewed by either looking at the coverage of a given evaluation

objective or by examining a given test location. These really define two different constraints to which one would like to optimize in the future.

Once several test strategies have been developed, they can be "ranked" subjectively based on coverage of evaluation objectives, number of Critical Operational Issues answered, or any other attributes, such as cost, resources, or schedule.

CONCLUSION

The real-world operational environment has changed, and AFOTEC needed to change accordingly. Joint Vision 2010, AF Global Engagement, and USAF Doctrine publications have all pointed out that the U.S. Department of Defense and Air Force must operate in a joint/coalition operational environment. Further, technology has provided the warfighter with a vastly more complex array of hardware and software which must operate together correctly to achieve full-spectrum dominance. In addition, today's joint/coalition force employment packages are much more integrated and interdependent (e.g. support aircraft, satellites, C4ISR, etc). The individual SUT most often requires inputs from other systems and provides information to other weapon systems as well. In response to the changes in warfighting and system complexity, AFOTEC developed and implemented an initiative to provide the warfighter key insights into mission accomplishment. This initiative included an implementation process, a software tool, and modified test report with separate sections devoted to system evaluation and OIAs. The systems evaluation section provides AFOTEC's traditional assessment of the system's operational effectiveness and suitability for the hands-on-operator/maintainer, as well as its capabilities to meet ORD threshold requirements. The OIA section provides an assessment of potential force employment/CONOPS issues affecting the deployment, employment, and sustainment of forces, weapon systems, and capabilities.

AFOTEC is a key partner with the acquisition and user communities, and these changes will help ensure the best weapon systems are provided to our warfighters.